DRAFT FOR Science Team Comment

Implementation of the GHRSST-PP High-Resolution Diagnostic Data Set (HR-DDS)

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Executive Summary

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1 Introduction

The Global Ocean Data Assimilation Experiment (GODAE) high-resolution sea surface temperature pilot project (GHRSST-PP) has been established to provide international focus and coordination for the development of a new generation of global, multi-sensor, high-resolution (better than 10 km), sea surface temperature (SST) products provided in real time (6 hourly). It provides a major contribution to the GODAE Common (Bell et al., 2002) as a measurement network as described in the GODAE implementation plan (Smith et al., 2002). Its primary aim is to oversee the development, timely delivery, assembly and processing of high-quality, global scale, SST products at a fine spatial and temporal resolution, for the diverse needs of GODAE and the wider scientific community.

The general concept of the GHRSST-PP is to merge and analyse complementary satellite and in situ measurements in real time that can in principle, deliver SST products with enhanced accuracy, spatial and temporal coverage. During the 2003-2005 GODAE demonstration phase, several new passive microwave and infrared waveband satellite instruments will provide unprecedented coverage of the global ocean in terms of coverage, accuracy and timeliness. The GHRSST-PP has a responsibility to demonstrate the usefulness of these data sets in an operational context in order to justify the required continuation of these instruments (Smith and Koblinsky, 2002).

GODAE users and user applications include:

- The ocean and atmosphere modelling community
- The NWP community
- The oceanographic science community
- Navy offices
- The climate community
- Governments and research agencies
- International projects (GOOS, CLIVAR etc.)
- Satellite data providers
- Satellite heat flux developers

A full description of the scientific rationale for the GHRSST-PP can be found in the ***GHRSST-PP Strategy and Initial Implementation*** (Donlon et al, 2002). The success of the GHRSST-PP depends on the correct specification, generation and distribution of mutually beneficial GHRSST-PP SST products that are available in real time. A full description of the GHRSST-PP data products can be found in the ***GHRSST-PP Data Product Specifications*** reference document. Innovative, but robust, data merging strategies and methods have to be developed and implemented in an operationally efficient manner, that optimise the resolution, coverage, accuracy and temporal characteristics of complementary satellite and in situ data. These have to be carefully balanced not only against limitations of data availability and throughput, but also against available human and computer resources. Due to the volume of data, the GHRSST-PP project strategy is based on sharing global processing and data management tasks by interconnected regional Data Assembly Centres. Full details of the GHRSST-PP, including all relevant documents can be found at the project web site located at http://www.ghrsst-pp.org.

1.1.1.1 Summary of the GHRSST-PP Implementation Model

The GHRSST-PP has adopted the implementation concept of **regional/*global task sharing*** by regional data product assembly centres (RDAC) interconnected by dedicated, fast data connections has been adopted. In this implementation model, regional centres are responsible for the generation of regional coverage GHRSST-PP data products typically defined by regional users and applications and/or geostationary satellite data coverage. In situ and satellite data are identically processed according to agreed GHRSST-PP methods and data product algorithms (specified by the ISDI-TAG) at each regional centre including the generation of error statistics and validation data sets. Regional data products and all ancillary data are then passed to a global data analysis centre where they are integrated as global data products using data not necessarily held by the regional data centres. This latter implementation concept is referred to as ***global integration***. Finally, data generated and maintained at both the global and regional centres is interfaced by a suite of services and tools that collectively provide **User Information and Services** (UIS). The specific application of GHRSST-PP data products by operational users encompassing a broad spectrum of activities will be actively fostered in a set of activities that actively engage the GHRSST-PP with operational user applications in an **Applications and User Services (AUS)** project component.

Figure 1 below provides a schematic overview of the GHRSST-PP. It proposes an implementation model built on a layered approach following the theme of ***Moving SST data to applications***. The right hand side of Figure 1 describes the GHRSST-PP implementation model that has five distinct layers:

1. ***Global and regional data provision layer.*** These activities are concerned with the real time ingestion of satellite and in situ data within the GHRSST-PP. They include the provision of specialist satellite data servers (e.g., NASDA server, ESA server) and the wider and more diverse network of specialist in situ data centres (e.g., CORIOLIS, NDBC).

2. ***Regional task sharing project layer.*** These are regional area projects (e.g., European Medspiration and Japanese New Generation SST projects) that will implement the GHRSST-PP. Collectively, these projects share the tasks that are required to provide GHRSST-PP global coverage data products and services a strategic implementation concept referred to as "***global task sharing***".
3. ***Regional data assembly, merging and analysis layer.*** These activities coordinate the outputs of the regional projects into the global task sharing framework of the GHRSST-PP. They define the necessary outputs (e.g., scope of data coverage) and interfaces (e.g., international data centre exchange protocols) to the upper project layers.
4. ***Global data merging and analysis layer.*** These activities realize a GODAE specialist data centre within the GODAE Measurement Network that provides global SST data products to the GODAE Common in real time.
5. ***User Application and services layer.*** These activities provide the necessary data serving and user interaction services required by specialist and non-specialist data users.

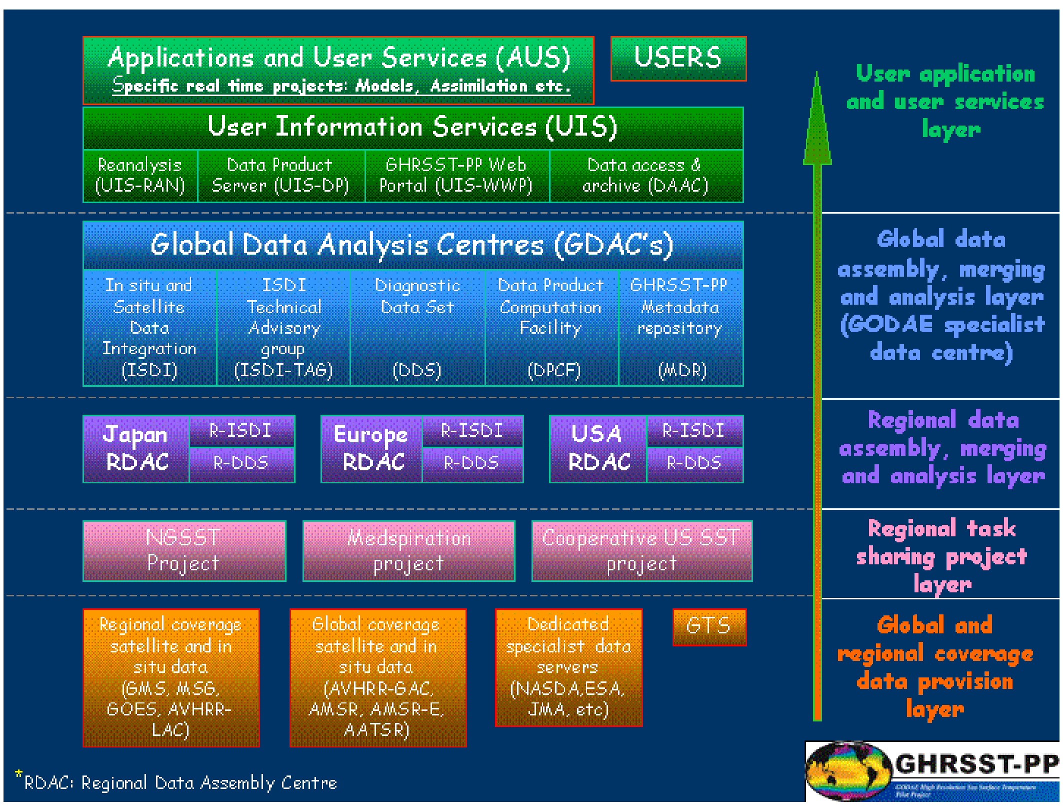

Figure 1 Schematic Overview of the GHRSST-PP Implementation plan identifying the major project components and services.

A full description of the GHRSST-PP Implementation model can be found in the ***GHRSST-PP Implementation plan*** available at http://www.ghrsst-pp.org.

1.2 The GHRSST-PP Diagnostic Data Set (DDS)

There are considerable challenges to developing the scientific algorithms required to provide GHRSST-PP data products. In particular, understanding the limitations and strengths of input data streams through validation and inter-comparison is necessary to identify, characterise and provide solutions that account for systematic differences that exist between input data streams. Once GHRSST-PP data products are being produced, there is a need to continually monitor the quality and performance of both the input data streams and the data products themselves through inter-comparison and validation analysis using in situ observations. The general concept of the GHRSST-PP Diagnostic Data Set (DDS) system is to provide a framework within the GHRSST-PP implementation model, infrastructure and a manageable data resource to address these challenges.

Satellite and in situ observations will be collected at many DDS sites, the DDS will provide a data set suitable for:

- the evaluation and monitoring of input satellite data streams
- evaluating and developing complementary satellite bias correction strategies
- helping to develop and test ISDI data-fusion approaches
- the validation and inter-comparison of GHRSST-PP data products.

The wider context of the GHRSST-PP DDS system (as specified in the GHRSST-PP Strategy) is to consider different levels of DDS activity according to the spatial and temporal scale of inter-comparison activities. Three related DDS data requirements were identified that consider data inter-comparison at pixel, regional and global resolution scales.

- **High-resolution DDS (HR-DDS):** The aim is to develop a data resource and framework for enabling pixel data inter-comparison and analysis at daily or even hourly resolution.
- **Regional DDS (R-DDS):** The activities within this module are concerned with comparison of daily and temporal-composite L2 and L3 data sets of moderate spatial resolution for a number of globally distributed regional areas. This is an activity that is directly relevant to the RDAC projects, having a focus towards existing regional interests and associated expertise and thus, enhances the value and quality of all data streams.

- **Global DDS (G-DDS):** This considers SST data at the global scale and involves evaluation and testing of global data streams and data sets. Although global, coarse resolution (0.25-10° spatial) scale L2 and L3 data composites will limit the level of data detail, inter-comparison activities will be similar to those for Regional DDS studies, there will be an increased focus on the climate qualities of the data and thus, require the use of in situ subsurface temperature measurements. At this level, it will also be possible to inter-compare SST products with other GOOS data and products (e.g., from *Argo* or altimetry).

Figure 1 shows that the DDS system has four components: A "master" DDS located at the GDAC together with regional project DDS systems functioning within the regional task sharing projects. These are interconnected by the GDAC metadata repository where a master index of all DDS data and GHRSST-PP data products resides. In this sense, the DDS system is a distributed system in which data may reside at a number of different globally distributed data centres. From a user perspective, the DDS appears as a single entity, accessed via Internet tools and data servers so that the exact location of data becomes irrelevant.

This report focuses on the implementation of the high-resolution DDS component which was considered a priority action for the GHRSST-PP at the Second GHRSST-PP Workshop "Removing the Barriers to the Implementation of the GHRSST-PP" held in Tokyo, May 2002 (Donlon, 2002). It serves as a reference document for the HR-DDS system and will evolve as more experience is gained implementing and using the HR-DDS system. Section 2 of this report describes the DDS service requirements and section 3 provides a detailed implementation model for the implementation of the high resolution DDS (HR-DDS) system including a description of the metadata model, database system, HR-DDS file structure, a description of data provision, user services and hardware implementation. The Annex provides specific technical data for the generation and provision of HR-DDS data sets by data providing agencies.

2 Service Requirements for the GHRSST-PP High Resolution Diagnostic Data Set

The primary HR-DDS activity focuses on the development and analysis of a time-series data set that will comprise of in-situ and satellite data collected at globally distributed, and where possible, instrumented sites. The location of these sites is such that they collectively characterise the range of global ocean and atmospheric conditions and must have a latitudinal distribution. At each site, satellite data considered pertinent to the GHRSST-PP effort (visible, infrared, passive and active microwave) will be automatically archived, preferably at source. The DDS will serve as a repository for match-up in situ and satellite data products that are regularly used in a variety of scientific analyses in support of GHRSST-PP workshops, data merger studies, and time series studies. A precedent for this type of approach is provided by the AVHRR Pathfinder Matchup Data base (Kilpatrick et al, 2001).

The following service requirements have been defined for the GHRSST-PP HR-DDS system:

i. Develop a data resource and framework that allows different satellite data to be inter-compared with each other at a pixel resolution and with in situ observations at the highest spatial and temporal resolution possible. The potentially enormous amounts of data that could be considered at a global level prohibit their effective analysis according to (i). Accordingly, the HR-DDS should comprise of a number of globally distributed 2° latitude x 2° longitude areas (or 'sites') for which all relevant data will be archived. This includes measurements from satellite sensors (SST, wind speed, water vapour, ocean colour, surface roughness, solar radiation) together with in situ oceanographic and atmospheric data (e.g. radiometric SST, subsurface SST and salinity at various depths, wind speed and direction, humidity, air temperature, solar radiation etc., including the height at which the measurements were taken) collected by a number of different instrument packages (e.g. profilers, buoys, above-water measurement devices) on a variety of different platforms including platforms, ships, moorings, and drifters.
ii. The HR-DDS is expected to provide diagnostic information that can be used to assure the quality of GHRSST-PP data products which will be produced at 6 hourly intervals. Issues of data delivery and timeliness are important within the HR-DDS to ensure the quality of GHRSST-PP data products. Feedback from HR-DDS activities will be critical for all other GHRSST-PP activities and, where a problem with an input data stream is encountered, to GHRSST-PP data providers themselves.

iii. There is a need for flexibility in terms of data exchange within the DDS itself where relatively small amounts of scientific data sets (in comparison to global SST maps) need to be exchanged on an hourly basis. A server-client mechanism and protocol is required to effectively access HR-DDS data by users that can be easily implemented at data provider and data user facilities is required. This should incur minimum overhead in terms of cost, development and maintenance.

iv. The HR-DDS should be implemented as a distributed archive linked together only by a central metadata repository. The metadata repository should provide the address for all HR-DDS holdings at a global level allowing users to access data irrespective of their actual location. As the data volumes are relatively small, a distributed archive has considerable advantages in terms of data transport for data providers, who may easily update and extend the data holdings as required and, to data users, who are often only interested in a specific regional data subset.

v. A WWW interface implementing a dedicated search engine that accesses the RDB is required together with basic tools enabling users to rapidly obtain metadata information and gain access to HR-DDS data holdings irrespective of their location is required.

vi. Careful quality control of all data within the HR-DDS is required (Emery et al. 2001; Kilpatrick et al, 2001) if the DDS concept is to be successful. In order to maintain data quality, relevant documentation and calibration files associated with all data must be stored within the DDS system, remain current and be available to the user community working within the DDS system.

vii. A HR-DDS system documentation and help facility is required to help new users take full advantage of all aspects of the HR-DDS and to facilitate the maintenance and management of the HR-DDS system. Descriptions and information describing current DDS activities including how to contribute to a specific activity should also be documented.

viii. To encourage the use and population of the HR-DDS, it should be an open system, allowing wide community access to all data holdings for scientific purposes.

The GHRSST-PP HR-DDS will benefit considerably by cultivating strong links to existing satellite sensor calibration and validation activities (e.g., SIMBIOS, NASDA, NASA, ESA) and other satellite and in situ match-up data base activities (e.g., MODIS, AVHRR Pathfinder). In particular, all GHRSST-PP DDS activities will be coordinated with the CEOS working group on satellite calibration and validation activates and results presented to the CEOS group at regular intervals.

The service requirements described here are considered in more detail within the following sections. In section 3, a detailed implementation model is described that describes how the HR-DDS system will be implemented.

3 Detailed HR-DDS Description

The following sections describe a detailed service specification for the GHRSST-PP HR-DDS system. The HR-DDS system should be implemented and tested during the GHRSST-PP preparation phase (2002-June 2003).

3.1 HR-DDS data content

HR-DDS service requirements will be achieved by creating and maintaining a time series of co-located satellite and in situ data at a number of globally distributed "sites". Most sites will be defined as 2° x 2° latitude x longitude areas and be globally distributed. Table 1 describes the satellite and in situ SST data sets and data sources that should ideally be ingested into the HR-DDS system in order for the GHRSST-PP to successfully develop and validate its own data products. The majority of GHRSST-PP data products are expected to be developed using a "core" set of satellite and in situ SST data that are more easily available to the community in an operational real time environment. Core data have been indicated as red highlights in Table 1. As other relevant data become available, these should be ingested into the HR-DDS system as and when available.

Table 1. Global and regional coverage satellite and in situ SST data streams to be ingested within the GHRSST-PP HR-DDS system during the period 2003-2005. Red highlights indicate "core" HR-DDS data.

	Global coverage	Regional coverage
Operational satellite data streams	AVHRR-GAC$	AVHRR-LAC#
	AATSR-1km#	GMS-VISSR#
	AATSR-17km$	MSG-SEVIRI#
	AATSR-0.5 degree$	GOES-E#
		GOES-W#
Research satellite data streams	AMSR$	TRMM TMI$
	AMSR-E$	TRMM VIRRS#
	GLI#	HY-1
	MODIS-aqua#	FY-1
	MODIS-terra#	
Operational in situ data streams	ARGO	TAO
	SOOP	PIRATA
	VOS/VOSCLIM	JMA
	Drifting buoy	EUMETSAT OSI-SAF
Research in situ data streams		Radiometer data
		Research cruises

High data rate $ Low data rate

In addition to SST data streams, the HR-DDS should also ingest wind speed and solar radiation data derived from satellite or measured in situ in order to characterise the thermal state of the ocean surface (SSTdepth-SSTskin differences and diurnal stratification studies). Cloud liquid water vapour should also be provided to assist in defining new cloud clearing methodologies and atmospheric correction strategies. These data and their likely source are described in Table 2.

Table 2. Global and regional coverage satellite and in situ ocean/atmosphere data streams to be ingested within the GHRSST-PP HR-DDS system during the period 2003-2005.

	Global coverage	Regional coverage
Operational satellite data streams	SSM/I wind speed ENVISAT RA-2 wind/wave data QuickScat wind speed	GMS-VISSR# derived solar radiation MSG-SEVIRI# derived solar radiation GOES-E# derived solar radiation GOES-W# derived solar radiation
Research satellite data streams	AMSR$ wind speed, cloud liquid water vapour AMSR-E$ wind speed, cloud liquid water vapour	TRMM TMI$ wind speed, cloud liquid water vapour
Operational in situ data streams	SOOP VOS/VOSCLIM Drifting buoy	TAO PIRATA JMA EUMETSAT OSI-SAF
Research in situ data streams		Research cruises

High data rate $ Low data rate

3.2 HR-DDS site locations

Following suggestions of the GHRSST-PP Science Team at the May 2002 GHRSST-PP meeting in Tokyo, and after circulation of a first version of the HR-DDS location map, a set of version 2 HR-DDS site locations have been selected according to the following general criteria.

- A manageable limit for the number of HR-DDS locations was considered 100-200 so as not to over-burden data providers.
- The HR-DDS should include high quality climate monitoring moored buoy locations. Note that drifting buoy measurements could also be included where the buoy drifts through one of the fixed HR-DDS locations.
- Locations should include sites with long-term in-situ observational infrastructure.
- HR-DDS sites should collectively provide an unbiased sample of all the world oceans to act as inter-satellite calibration windows over an unbiased sample of geophysical conditions.
- The HR-DDS should include a number of well distributed coastal land areas to be used as geolocation quality controls.
- A number of HR-DDS sites should encompass the polar region marginal ice zones.
- Where appropriate, HR-DDS sites should make use of and mutually support other similar diagnostic data set activities such as that of the SIMBIOS program.

Three types of HR-DDS site are foreseen following the definitions adopted by the SIMBIOS working group on merger activities (Campbell, 2001):

- **Category 1** sites that provide a comprehensive suite of in situ observations that could be used for vicarious calibration of satellite sensors and are likely to constitute only a small fraction of the DDS (e.g., regular SOO transects, IMET buoys, SURFA sites, platform observations).
- **Category 2** sites that provide satellite and when available, in situ data, as a time series that are likely to constitute the main component of the HR-DDS.
- **Category 3** sites that consider any other contemporaneous data on an ad hoc basis (e.g., scientific cruise data sets, drifting buoy observations etc.).

Ideally, the HR-DDS should contain sufficient information to process satellite data from level L1B through to L2 (as defined in Table 3) although it is recognised that this is extremely demanding and probably beyond the scope of the GHRSST-PP. However, the HR-DDS provides a mechanism to entrain Level 0 and/or additional data if required. In addition to directly related SST parameters, data will also be archived to assess the surface wind speed and total water vapour content that provide important additional information describing the atmosphere and ocean conditions at the time of measurement.

Table 3. Satellite Data Processing Levels.

Level	Description
Level 0	Unprocessed instrument and payload data at full resolution.
Level 1A	Reconstructed unprocessed instrument data at full resolution, time referenced, and annotated with ancillary information, including radiometric and geometric calibration coefficients and geo-referencing parameters, computed and appended, but not applied, to the Level 0 data.
Level 1B	Level 1A data that have been processed to sensor units.
Level 2	Geophysical variables derived from Level 1 source data at the same resolution and location as the Level 1 data.
Level 3	Level 2 variables mapped on uniform space-time grid scales.
Level 4	Results from analyses of lower level data (e.g., variables derived from multiple measurements).

Figure 2 shows the location of all GHRSST-PP HR-DDS sites which include the TAO/TRITON array, the PIRATA array and the DDS sites proposed by the SIMBIOS project (Campbell, 2001). Annex I provides a complete geographical specification for each GHRSST-PP HR-DDS site.

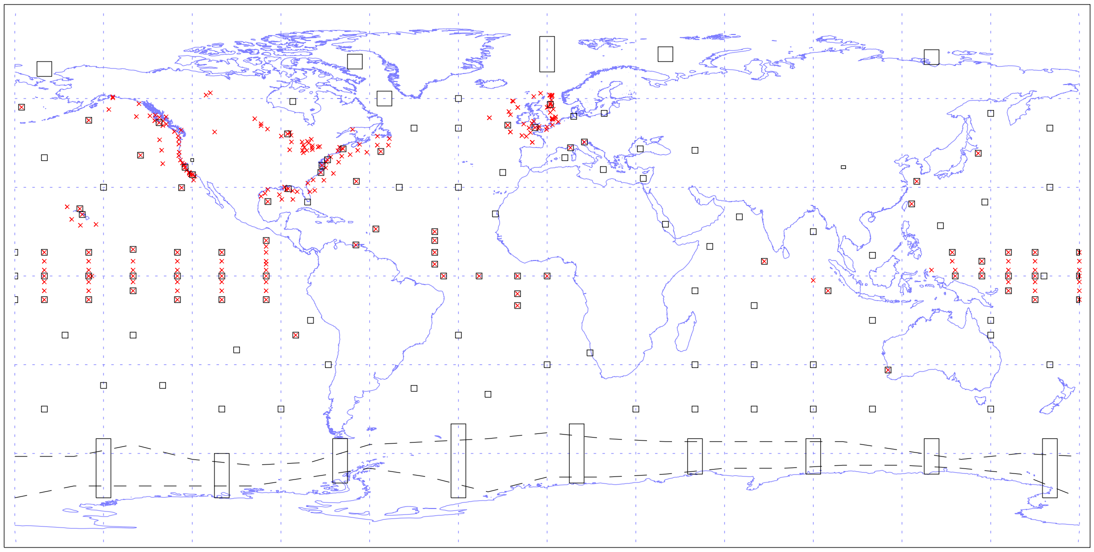

Figure 2. GHRSST-PP HR-DDS v2.2 locations are marked as rectangular boxes. Locations are based on the GHRSST-PP Science Team review at the Second GHRSST-PP Workshop. Moored buoys and SIMBIOS sites are marked with crosses, and the seasonal limits of the Antarctic ice edge are shown by dashed lines.

3.3 Data exchange within a distributed HR-DDS framework

The Distributed Oceanographic Data system (DODS) is a framework for scientific data networking that simplifies all aspects of remote data access. It is widely implemented and well supported, already operational and provides access to a considerable oceanographic data resource. The design of DODS was based on two considerations:

- data are often most appropriately distributed by the individual or group that has developed them and,
- users generally prefer to access data from a familiar application software package.

DODS uses existing network protocols to allow direct access to any compatible data sets that activities care to make available. It uses existing, well understood technologies (based on the HTTP protocol) to transfer data via the internet seamlessly providing users access to data in a variety of

different formats. Furthermore, it can translate between data formats thus providing a framework for a highly distributed system that allows users to control the distribution of their own data and the way they access data from remote sites. Local data can be made accessible to remote locations regardless of local storage format by using local DODS servers. US-GODAE already host DODS servers on the Monterey site and partner servers including PO.DAAC, NAVOCEANO, NASA/GSFC, NCAR, NOAA, and US-GLOBEC also use the DODS system. DODS currently serves 6144x6144 (16 bit) SST images stored in HDF format. A "chunking" system facilitates data transfer: the image is broken up into 512x512 compressed chunks (the size used here is defined by the data provider). A remote DODS request (via http) pulls the image chunks of interest, decompress them, reassembles them, and then extracts a requested area from the image. This is very fast for small images. The entire SST image or a sub-sampled field may also be requested and the transfer time required is similar to that required to decompress the entire image. The DODS system, together with ftp, provides an elegant and extremely flexible solution for the GHRSST-PP HR-DDS data transfer system requiring minimal investment (it is freely available) in terms of configuration and operation while maximising data access within the HR-DDS. DODS servers installed at HR-DDS data provider sites, RDAC and GDAC can be accessed by users using one of several DODS clients (including IDL, Matlab, and standard web-browsers). Full details of the DODS system can be found at
http://www.unidata.ucar.edu/packages/dods/

The distribution of HR-DDS data from Data Provider to Data User will be primarily via the internet using DODS as the server. DODS allows a user to examine a data set and view its structure, format and contents before choosing to download the data themselves and, to extract all or part of the data set.

3.4 HR-DDS file format standard

The HR-DDS file format standard has been designed to be compatible with the GODAE Data Sharing Pilot data sets and application tools, but also to be simple avoid overburdening data providers with a lot of tricky re-formatting.

HR-DDS data files can be encoded in either netCDF (version 3) or plain ASCII text formats. The netCDF format provides capabilities to store multidimensional data arrays together with information describing the data in a single file, and is thus useful for storing many different types of scientific data. The plain ASCII text format is only to be used with point time-series data which can be represented as a 2-D table, such as oceanographic measurements from buoys. There are no recommendations for the ASCII

HR-DDS format, beyond that the columns of the tabular data should be clearly labelled with meaningful names, and include generally accepted, preferably S.I., units for every column. The rest of this section applies to the netCDF format only.

The following web sites contain reference documents that are essential reading for those about to create HR-DDS data files:

netCDF:	http://www.unidata.ucar.edu/packages/netcdf/
CF conventions:	http://www.cgd.ucar.edu/cms/eaton/cf-metadata/
UDUNITS:	http://www.unidata.ucar.edu/packages/udunits/

In parallel with the GODAE Data Sharing Pilot project, HR-DDS netCDF files should be compatible with the NetCDF Climate and Forecast (CF) conventions.

3.4.1 Overall structure and examples

A netCDF format file consists of multidimensional data arrays (*variables*) and information about them (*attributes*). The axes along the edges of the multidimensional data arrays are termed *dimensions*, and are also explicitly defined within the netCDF file.

Beginning with some examples, Table 4 shows the structure of a simple HR-DDS data file which contains a two-dimensional array of sea-surface temperatures. Note that in netCDF-speak the word *variable* is used to refer to data stored in the file as a vector or multidimensional array. Global attributes (rows 1-14 of Table 4) are used to hold information which applies to the whole file, such as the data set title. The global attributes shown in the example of Table 4 are the minimum set required for an HR-DDS file. The **title**, **entry_id**, **contact** and **Conventions** attributes would normally be the same for all data files within a data set.

Each individual variable can also have its own attributes. The variable SST consists of a 2-D array of sea-surface temperature measurements. In order to save disk space, the 32-bit floating point temperature measurements have been scaled onto 16-bit short integers using the **add_offset** and **scale_factor** attributes. The floating point SST values can be recovered using:

$$SST_{float} = (\textbf{scale\_factor} \times SST_{short}) + \textbf{add\_offset}$$

Also associated with the SST variable are attributes describing the units, a longer descriptive version of the variable name, and a fill value. Units should be described by a chracter string which is compatible with the Unidata UDUNITS package, and preferably be S.I. (see Annex 3). The fill value is used to indicate array elements that do not contain a valid measurement for whatever reason (cloudiness, missing data, *etc.*).

Two other variables are included which provide the scales for the latitude and longitude axes of the SST array, these are the so-called *coordinate variables*. These coordinate variables have not been transformed from floating point to integers, since they take up only a small fraction of the total required disk space. The only attributes defined in this case are the units. No fill value attribute is defined because vector coordinate variables should never have missing values.

Table 4. A simple HR-DDS file containing a single SST variable.

	Variable	Attribute	Type	Notes
1		**title**	char	*e.g.* "ATSR-2 dual view daytime sea-surface temperature"
2		**entry_id**	char	Same as metadata field **Entry_ID** (see §3.5).
3		**location**	char	HR-DDS site name, *e.g.*"ghr001"
4		**creation_date**	char: "yyyy-mm-dd"	*e.g.* "2002-10-16"
5		**start_date**	char: "yyyy-mm-dd"	UTC, *e.g.* "1999-07-01"
6		**start_time**	char: "hh:mm:ss"	UTC, *e.g.* "14:12:59"
7		**stop_date**	char: "yyyy-mm-dd"	UTC, *e.g.* "1999-07-01"
8		**stop_time**	char: "hh:mm:ss"	UTC, *e.g.* "14:13:02"
9		**southernmost_latitude**	float	*e.g.* 34.0
10		**northernmost_latitude**	float	*e.g.* 36.0
11		**westernmost_longitude**	float	*e.g.* -16.0
12		**easternmost_longitude**	float	*e.g.* -14.0
13		**contact**	char	
14		**Conventions**	char	"CF-1.0"
15	SST		short[*n*][*m*]	2-D array (*n* rows by *m* columns)
16		**long_name**	char	*e.g.*"sea surface temperature"
17		**units**	char	"Celsius"
18		**_FillValue**	short	*e.g.* -32768
19		**add_offset**	float	*e.g.* 0.0
20		**scale_factor**	float	*e.g.* 0.01
21	longitude		float[*m*]	longitude coordinate variable
22		**units**	char	"degrees_east"
23	latitude		float[*n*]	latitude coordinante variable
24		**units**	char	"degrees_north"

Table 5 shows a more complicated example of an HR-DDS file containing AVHRR brightness temperature measurements in two infrared channels plus a combined land/sea and cloud mask. Here the arrays are on the original satellite image grid with netCDF dimensions of "pixel" (*m*) and "scanline" (*n*). Since the satellite image grid axes don't correspond to geographic coordinates the 1-D latitude and longitude coordinate variables cannot be defined. Instead, two 2-D arrays are needed, each element of which contains the latitude or longitude coordinate of the corresponding pixel in the brightness temperature and flag arrays. Note that since the coordinates are now held in large 2-D arrays, they have also been scaled onto 16-bit short integers to save disk space. The coordinate arrays can also have fill values now, as the rectangular subset of the satellite image raster doesn't fit exactly over the HR-DDS site (rectangular in lat-lon), leaving large triangular areas of empty array elements in the corners.

Table 5. A more complex HR-DDS file containing data on the original satellite image grid.

Variable	Attribute	Type	Notes
	title	char	"NOAA-14 AVHRR GAC Ascending Pass"
...	*Rest of global attributes as shown in Table 4…*	...	...
flags		byte[*n*][*m*]	2-D array (*n* rows by *m* cols)
	long_name	char	"cloud and land masks"
	units	char	"none"
	Meaning	char	bit[0] set => land (least significant bit) bit[1] set => cloudy
	_FillValue	byte	128 (bit[7] set)
ch4		short[*n*][*m*]	2-D array (*n* rows by *m* cols)
	long_name	char	"AVHRR channel 4 brightness temperature"
	units	char	"kelvin"
	_FillValue	short	-32768
	add_offset	float	273.15
	scale_factor	float	0.01
ch5		short[*n*][*m*]	2-D array (*n* rows by *m* cols)
	long_name	char	"AVHRR channel 5 brightness temperature"
	units	char	"kelvin"
	_FillValue	short	-32768
	add_offset	float	273.15
	scale_factor	float	0.01
longitude		short[*n*][*m*]	longitude coordinate array
	units	char	"degrees_east"
	_FillValue	short	-32768
	add_offset	float	0.0
	scale_factor	float	0.0055
latitude		short[*n*][*m*]	latitude coordinate array
	units	char	"degrees_north"
	_FillValue	short	-32768
	add_offset	float	0.0
	scale_factor	float	0.0055

Table 6 shows an HR-DDS file containing time series's of water vapour and wind speed measurements as 3-D arrays. The third dimension provides the UDUNITS compatible time coordinate, which in this case is in units of days relative to the beginning of the year. All time coordinates should include such a reference time in the units definition (see the CF Conventions document, §3.4).

Table 6. An HR-DDS containing time-series data in 3-D arrays.

Variable	Attribute	Type	Notes
	title	char	"SSM/I (F15) ascending data set over ghr001 for 1999 "
...	*Rest of global attributes...*	...	...
time		short[*p*]	
	units	char	"days since 1999-01-01 00:00:00"
latitude		float[*q*]	
	units	char	"degrees_north"
longitude		float[*r*]	
	units	char	"degrees_east"
W		byte[*p*][*q*][*r*]	

	long_name	char	"10m surface wind speed"
	units	char	"metre/second"
	_FillValue	byte	255
	add_offset	float	0.0
	scale_factor	float	0.2
V		byte[*p*][*q*][*r*]	
	long_name	char	"atmospheric water vapour"
	units	char	"millimetres"
	_FillValue	byte	255
	add_offset	float	0.0
	scale_factor	float	0.3

3.4.2 Detailed description

Global Attributes

The following global attributes are required:

- **title:** (char[160]) A descriptive title for the data set.
- **entry_id:** (char[31]) A unique identifier for the data set, allocated by the GHRSST-PP Project Office. Same as the **Entry_ID** metadata field (§3.5).
- **location:** (char [80]) HR-DDS name, taken from the set of valid location keywords (see §6).
- **creation_date:** (char[10], in format "yyyy-mm-dd") Date the data file was created (local time).
- **start_time:** (char[8], "hh:mm:ss" UTC) Start time of the data in universal time coordinated (UTC; ~ Greenwich Mean Time)
- **stop_time**: (char[8], "hh:mm:ss" UTC) End time of the data in universal time coordinated (UTC; ~ Greenwich Mean Time)
- **start_date**: (char[10], "yyyy-mm-dd" UTC) Start date of the datain universal time coordinated (UTC; ~ Greenwich Mean Time).
- **stop_date:** (char[10], "yyyy-mm-dd" UTC) End date of the data in universal time coordinated (UTC; ~ Greenwich Mean Time).
- **northernmost_latitude:** (float, degrees north, range -90° to +90°)
- **southernmost_latitude**: (float, degrees north, range -90° to +90°)
- **easternmost_longitude:** (float, degrees east, range -180° to +180°)
- **westernmost_longitude:** (float, degrees east, range -180° to +180°)
- **contact**: (char) A free text string giving the primary contact for information about the data set.
- **Conventions:** (char) A text string identifying the netCDF convention followed. This attribute should be set to "CF-1.0" to indicate compatibility with the Climate and Forecast (CF) netCDF convention.

Variable Attributes

The following two variable attributes are required:

- **_FillValue:** (Same data type as variable) A value used to indicate array elements containing no valid data.
- **units**: (char) Text description of the units, preferably S.I., and must be compatible with the Unidata UDUNITS package. Annex 3 provides a list of acceptable unit names.

The following variable attributes may also be usefully included:

- **scale_factor:** (Same data type as variable) To be multiplied by the variable to recover the original value.
- **add_offset**: (Same data type as variable) To be added to the variable after multiplying by the scale factor to recover the original value. If only one of scale_factor or add_offset are needed, then both should be included anyway to avoid ambiguity, with **scale_factor** defaulting to 1.0 and **add_offset** defaulting to 0.0.
- **long_name:** (char) A long version of the variable name, which should be the same as in the HRDDS metadata Parameters group.
- **meaning**: (char) A free text description of the variable, providing more detailed information than the **long_name** attribute.
- **valid_min:** (Same data type as variable) Minimum valid value for this variable.
- **valid_max:** (Same data type as variable) Maximum valid value for this variable. The fill value should be outside this valid range.

Any other attributes may also be added if considered useful. In particular, the use of the following attributes from the CF convention are encouraged:

- **standard_name:** (char) A standard and unique description of a physical quantity. For the complete list of standard name strings, see http://www.cgd.ucar.edu/cms/eaton/netcdf/standard_name.html.
- **source:** (char) Method of production of the original data.
- **institution:** (char) Where the data was originally produced.
- **references:** (char) References that describe the data or the methods used to produce it.
- **history:** (char) List of the applications that have modified the original data.
- **axis:** (char[1]) Assigns a default axis direction to help applications decide how to plot the data. Possible values are X, Y, Z, or T.
- **positive:** (char) Indicates the real-world direction of a coordinate variable ("up" or "down"). *E.g.*, a depth or atmospheric pressure coordinate would have this attribute set to "down".
- **coordinates:** (char) Identifies auxiliary coordinate variables, such as 2-D lat-lon coordinate arrays, label variables, and alternative coordinate variables.
- **comment:** (char) Miscellaneous information about the data or the methods used to produce it.

See the CF convention documentation for more details on the use of these attributes.

Coordinate Variables
Coordinate variables provide scales for the space and time axes for the multidimensional data arrays, and must be included for all dimensions that can be identified as spatiotemporal axes. Coordinate variables come in two types:

Coordinate vectors are used for data arrays located on orthogonal (but not necessarily regularly spaced) grids, such as a geographic (lat-lon) map projections. The only required attribute is **units**. The elements of a coordinate vector array should be in monotonically increasing or decreasing order. The data type can be any and scaling may be implemented if required.

Coordinate arrays are used to geolocate data arrays on non-orthogonal grids, such as images in the original pixel/scanline space, or complicated map projections. Required attributes are **units** and **_FillValue**. Elements of the coordinate array need not be mononically ordered. The data type can be any and scaling may be implemented if required.

Variables
A variable is a multidimensional array stored inside a netCDF file. The rank can be 1 (*i.e.* vector), 2 (*i.e.* array), or more as required. The variable name should be short and sweet, to aid the user in writing code to extract it. The optional **long_name** attribute is provided for a detailed and unambiguous description of the variable. Variables can be of any data type, and it is recommended to use the **add_offset** and **scale_factor** attributes to implement scaling functions to reduce the data volume. There may be as many variables included within one HR-DDS file as necessary.

It is recommended that array dimensions in C/C++ are ordered T, Z, Y, X, where X and Y are the two horizontal spatial dimensions, Z is the vertical, and T is time, with X the fastest varying dimension and T the slowest. FORTRAN arrays dimensions should be defined in the opposite order (X,Y,Z,T). Other dimensions should be added to the left of this list in C/C++, or to the right in FORTRAN.

3.4.3 File names and directories

Since the data file names are specified by the metadata, a file naming convention is not strictly necessary. The file name's purpose is to give a unique and human-recognisable designation to each HR-DDS data granule.

Because of the wide range of data types that can form a HR-DDS dataset, it is difficult to devise an easy to use file name convention that also ensures a unique designation for each data type. We therefore propose only some guidelines, which are likely to be expanded as new data types are introduced into the HR-DDS archive.

Table 7 lists the meaning of each part of the recommended HR-DDS file name. The file name should contain either a start time or a period field, but probably not both, nor neither. Irrelevant fields should be dropped. The field separator is an underscore, except for the last field, format, which is preceded by a full stop. These filenames are then compatible with both UNIX and Microsoft operating systems. Note that the only firm requirement is that NetCDF filenames *must* end with the ".nc" extension (CF-Conventions).

Table 7. Filename structure for GHRSST-PP HR-DDS data files

Field Name	Example	Comment
HR-DDS marker	hrdds	All HR-DDS file names should start with this prefix
DDS name	ghr002, tao023	Name of the DDS location
Data source	atsr2, n14avhrrgac, pirata27	Sensor name, rather than data provider
Data type	sst, windspeed, image, multi	multi = Multiple data types in the same file
Start date	19991231 (yyyymmdd)	UTC
Start time	235959 (hhmmss)	UTC
Period	1day, 30day, 1mth, 12mth, 1yr	Avoid unit of "week", use 7day instead
Format	.nc (netCDF), .txt (ASCII)	Preferred format is netCDF version 3

Example filenames following this structure include :

- hrdds_pir032_atsr2_sst_19990101_1day.nc
- hrdds_pir032_pirata_multi_19990101_1mth.nc
- hrdds_pir032_n14avhrrgac_image_19990101_125959.nc

New data types should attempt to follow the spirit of these conventions, as far as is reasonable.

HR-DDS data files will be archived in directories accessible by FTP, with the directory names being the same as the corresponding metadata **Entry_ID** field (see next section). Large collections can be further sub-divided by year of observation, if necessary.

3.5 HR-DDS metadata repository

The DODS framework only provides a means to ***access data*** – it does not provide the means to ***discover*** and select specific data a user would like to work with. In order for a user to address a particular scientific question, they must be able to find a specific set of data held within the HR-DDS system. In order to address this issue, the HR-DDS requires a searchable metadata database similar to the NASA Global Change Master Directory (GCMD, http://gcmd.gsfc.nasa.gov) to allow users to select the data they would like to access using the DODS server-client system.

The HR-DDS metadata repository is a physical database containing metadata descriptions of all data holdings within the HR-DDS. A minimum set of geo-spatial information describing a particular HR-DDS site data granule (in situ observation, satellite image) that resides in the HR-DDS data archive will be automatically stored within the database system. It is required to ensure that all data resources are "visible" to the users and it is the "core" of the HR-DDS data management framework. It provides a searchable catalogue of the distributed HR-DDS data holdings providing information on its physical location, contents and any constraints on its use. Without a master catalogue, it would be extremely difficult (if not impossible) to locate a single data resource within the HR-DDS system without physically connecting to the computers storing the data and searching each one individually.

A direct link between users and the master metadata index is required so metadata records can be administered by external users independently of the data resources themselves. The HR-DDS system will use a user configurable WWW browser interface to query the HR-DDS data catalogue that will provide:

(a) DODS syntax data request URL strings that can be used to extract HR-DDS data for local use
(b) Direct access to specific HR-DDS data sets via the DODS WWW browser interface.

3.5.1 Metadata format description

The metadata standard defined for HR-DDS is based on the GCMD DIF standard. It's not identical, but we have tried to keep it close to the GCMD standard in order to both capitalise on users' existing familiarity with GCMD, and so that the Data Set Record can form the basis for creation of an entry in the GCMD DIF database.

HR-DDS metadata consists of two types of record. The Data Set Record contains information which is common to all the files in the data set, such as the title and contact information. Each file in the data set is then represented by a File Record, which contains the information that distinguishes that file from all others in the data set. Table 8 and Table 9 show these two types of metadata record. The individual fields are explained in more detail below.

Field Name	Required?	Type	Max Length (bytes)
Entry_ID	yes	char	31
Entry_Title	yes	char	160
Data_Set_URL	yes	char	512
Group: Dataset Citation			
Dataset_Creator	yes	char	160
Dataset_Title	no	char	160
Dataset_Release_Date	yes	char	80
Dataset_Release_Place	no	char	80
Dataset_Publisher	yes	char	80
Version	yes	char	80
Issue_Identification	no	char	80
Data_Presentation_Form	no	char	80
Other_Citation_Details	no	char	160
Online_Resource	no	char	160
Group: Parameters			
Category_Topic_Term	yes	keyword	
Variable	no	keyword	
Detailed_Variable	no	char	80
Sensor_Name	yes	keyword	
Access_Constraints	no	char	1024
Use_Constraints	no	char	1024
Group: Data Center			
Data_Center_Name	yes	keyword	
Data_Center_URL	no	char	160
Data_Set_ID	no	char	160
Group: Personnel			
First_Name	no	char	80
Middle_Name	no	char	80
Last_Name	no	char	80
Email	no	char	80
Phone	no	char	80
Fax	no	char	80
Address	no	char	1024
Summary	yes	char	2048

Location	yes	keyword	
Metadata_Version	yes	char	31
Metadata_Creation_Date	yes	char	10
Metadata_Last_Revision_Date	yes	char	10

Table 8. Structure template for a GHRSST-PP HR-DDS metadata Data_Set_Record (v3.0a, 21/10/2002).

Field Name	Required?	Type	Max Length (bytes)
Entry_ID	yes	char	31
Data_File_URL	yes	char	512
Group: Temporal Coverage			
Start_Date	yes	char	10
Start_Time	yes	char	8
Stop_Date	yes	char	10
Stop_Time	yes	char	8
Group: Spatial Coverage			
Southernmost_Latitude	yes	float	4
Northernmost_Latitude	yes	float	4
Westernmost_Longitude	yes	float	4
Easternmost_Longitude	yes	float	4
Minumum_Altitude	no	char	80
Maximum_Altitude	no	char	80
Minumum_Depth	no	char	80
Maximum_Depth	no	char	80
Group: Data Resolution			
Spatial_Resolution	yes	char	80
Temporal_Resolution	yes	char	80
Altitude_Resolution	no	char	80
Depth_Resolution	no	char	80
Group: Projection_Information			
Projection_Type	no	keyword	
Ellipsoid_Type	no	keyword	
Other_Projection_Details	no	char	160
Metadata_Creation_Date	yes	char	10
Metadata_Last_Revision_Date	yes	char	10

Table 9. Structure template for a GHRSST-PP HR-DDS metadata File_Record (v3.0a, 21/10/2002).

3.5.1.1 GHRSST-PP HR-DDS Metadata Field Definitions

Much of the following text is closely based on the GCMD DIF definition document available at http://gcmd.gsfc.nasa.gov. Note that all fields of type "char" consist of characters from the entire printable ASCII character set. Up-to-date lists of valid keywords are available from the http://www.ghrsst-pp.org web site. Where new keywords are needed, *e.g.* for new sensors, a request should be sent to the GHRSST-PP Project Office.

Entry_ID

A unique identifier for the data set. It will be allocated by the GHRSST-PP Project Office in order to maintain its uniqueness. One to 31 alphanumeric characters permitted, including underscore (_), hyphen (-) and dot (.)

Entry_Title

A descriptive title for the data set.

- Title should be descriptive enough so that when a user is presented with a long list of titles, the user can determine the general content of the data set.
- In order to make titles descriptive, important elements about the data may be included in the title, *i.e.,* parameters measured, geographic location, instrument, investigator, project, temporal coverage.
- For readability, capitalization of the title should follow standard constructs. Do not use all capital letters or all lower case letters, but use the appropriate case where applicable.

Example

"Sea Surface Temperature from the Along-Track Scanning Radiometer 2 (ATSR-2), 1km resolution, daily, global, for the year 1999, from the Rutherford Appleton Laboratory, UK"

Data_Set_URL

The URL providing direct manual FTP access to the directory containing the dataset, for those wishing to download the whole data set in one go.

Group: Data_Set_Citation

A citation for the data set to properly credit the data set producer. This field has two functions:

1. to indicate how this data set should be cited in the professional scientific literature, and
2. if this data set is a compilation of other data sets, to document and credit the data sets that were used in producing this compilation.

This field is not to be used to list bibliographic references of scientific research articles arising from the data set. This field provides a citation for the data set itself, not articles related to the research results.

Dataset_Creator

The name of the organization(s) or individual(s) with primary intellectual responsibility for the data set's development.

Dataset_Title

The title of the data set; this may be the same as Entry Title.

Dataset_Release_Date

The date when the data set was made available for release.

Dataset_Release_Place

The name of the city (and state or province and country if needed) where the data set was made available for release.

Dataset_Publisher

The name of the individual or organization that made the data set available for release.

Version

The version of the data set.

Issue_Identification

The volume or issue number of the publication.

Data_Presentation_Form

The mode in which the data are represented, *e.g.* atlas, image, profile, etc.

Other_Citation_Details

Any other details.

Online_Resource

The URL of an online computer resource containing user-oriented information about the data set (e.g. help files, articles), if it exists.

Group: Parameters

This group describes the types of measurements represented by the data, such as sea surface temperature, windspeed, *etc*.

Category_Topic_Term

This is a concatenation of the three GCMD DIF keyword fields: Category, Topic and Term, which cover a fairly exhaustive range of data types. Units should be stated in the data files themselves.

Variable

Another keyword provding further specification of the measurement type.

Detailed_Variable
A free text field for provding further specification of the measurement type.

Sensor_Name
The instrument or hardware used to acquire the data.

Access_Constraints
Restrictions, limitations and legal prerequisites for accessing the data set. Some words which may be used in this field include: Public, In-house, Limited, Source. e.g. "Data available to the general public after 5 year embargo period beginning January 1, 1994"

Use_Constraints
Restrictions, limitations and legal prerequisites for using the data set. e.g. "Data may not be used for commercial applications".

Group: Data_Center
Identifies the data centre which distributes the data, the data centre URL, data set identification, and a person to contact. Note US spelling of centre.

Data_Center_Name
Name of the data centre taken from the list of valid keywords. Data centres which are part of a larger organization may have a compound short name made up of the organization short name and the data center short name; for example: INPE/DAE/FISAT. This is helpful for users conducting broad searches because the users may query on the substring INPE and receive all metadata records from INPE, regardless of division.

Data_Center_URL

The Internet Uniform Resource Locator(s) (URL) for the data centre should be listed if available. This field may be repeated as many times as necessary within the data centre group. The URLs will be hypertext linked. The URLs may include gopher, ftp and telnet as well as WWW servers:

Data_Center_URL: http://daac.gsfc.nasa.gov

Data_Center_URL: ftp://podaac.jpl.nasa.gov

Data_Center_URL: telnet://ncar.ucar.edu

Data_Center_URL: gopher://www.ciesin.org

Data_Set_ID

Should be listed if available. These are identification codes assigned by the data centre, which will simplify the location and ordering of the data sets.

Group: Personnel

This should be the primary contact person at the data centre who is able to respond to requests for and queries about the data. Most fields are self-explanatory. Address should be a valid postal address for the named person.

Summary

A brief description of the data set, descriptive enough to allow potential users of the data set to determine if the data set is useful for their needs.

- Should include information needed for a user to determine the usefulness of the data set.
- Should start with a topic sentence, describing what information is in the data set. Often, this is some measurable quantity or quantities, such as sea surface temperature, human population density, or species mortality rate.
- The total length should consist of approximately 30 lines, with each line not exceeding 80 characters, and separated by a carriage return (or carriage return + line feed) character.
- Should restate information that may be found in other fields if that information is vital to the understanding of the data set (*e.g.*, parameters, spatial coverage).
- Should reference the source information if the summary was abstracted from an existing document.
- Single spaced with blank lines separating paragraphs
- Capitalization should follow standard constructs. For readability, do not use all capital letters or all lower case letters, but use the appropriate case where applicable.
- No right justification
- Acronyms should be expanded to improve understanding.
- May contain tabular information
- Hyperlinked URLs may be embedded in the text by surrounding them with single or double quotes:

    - "http://www.ngdc.noaa.gov"

- Where applicable, should include brief statements of the following important information:
    - Data processing information (gridded, binned, swath, raw, algorithms used, necessary ancillary data sets)
    - Methodology or analytical tools
    - Time gaps in data set coverage
    - Units and unit resolution
    - Similarities and differences of these data to other closely-related data sets
    - Other pertinent information

Example

This Seasat data set contains Level 1b altimeter data. The parameters are the satellite height above the sea surface (from the altimeter), sigma-naught, and the satellite height with respect to the reference ellipsoid from orbit determination.

SEASAT was launched on June 28, 1978, carrying a five sensor payload, and operated successfully until a power failure brought transmission to a stop on October 10, 1978. Its height and inclination were 791 km and 108.0 deg., respectively.

The objective of the altimeter (ALT) was to determine ocean topography with a height measurement precision of 10 cm. Altitude was determined by measuring the time required for a pulse to be transmitted, reflected from the ocean surface and received by the altimeter. The ALT carrier frequency was 13.5 GHz and operated in chirp pulse mode with a 3.2 micro-sec uncompressed pulse width and 3.125 nano-sec compressed pulse width. The pulse limited footprint diameter was 1.2 km for calm seas and 12 km for rough seas.

Related Data Sets: SEASAT ALT(levels 1a, 2)
SMMR(levels 1a, 1b, 2),
SASS(levels 1a, 1b, 2) and
VIRR(level 1a)

Location

Name of the HR-DDS site. This field will be an important key for user searches of the database.

Metadata_Version

A number providing the metadata version, e.g. "2.1". Only valid version numbers should be used - check with the www.ghrsst-pp.org web site.

Metadata_Creation_Date
The date the metadata was created. Years should be four-digits. Month and day of month should be two digits, with leading zeroes if necessary

Metadata_Last_Revision_Date
The date the metadata was last revised. Format must be "yyyy-mm-dd". Years should be four-digits. Month and day of month should be two digits, with leading zeroes if necessary

Data_File_URL
This is a URL providing direct DODS access to the HR-DDS data file.

Group: Temporal_Coverage
Provides the start and end date and times for the measurements contained in the HR-DDS file. All date and times must be in Universal Time Coordinates (UTC, which is approx. Greenwich Mean Time), and formatted at "yyyy-mm-dd" for dates and "hh:mm:ss" for times.

Group: Spatial_Coverage
Geographic coverage (horizontal and vertical) of the data described. Longitude must be expressed in the range -180.0 to +360.0 as an offset from the Greenwich meridian, and latitude in the range -90.0 to +90.0, as an offset from the Equator. For gridded data, these coordinates should be the outer edges of the coverage, and not the coordinates of the centres of the edge pixels.

Minimum Altitude: the altitude level which represents the lower limit of data coverage, as measured from mean sea level. Maximum Altitude: the altitude level which represents the higher limit of data coverage, as measured from mean sea level. Minimum Depth: the depth level which represents the upper-most depth of data coverage, as measured from mean sea level. Maximum Depth: the depth level which represents the lowest depth of data coverage, as measured from mean sea level.

Group: Projection_Information

Projection
A keyword from the GHRSST-PP approved list of projection names.

Ellipsoid_Type
A keyword from the GHRSST-PP approved list of ellipsoids.

Other_Projection_Details
Free text description of details such as the projections standard parrallels, *etc.*, if necessary to fully specify the projection.

3.6 Why is the HR-DDS designed like this?

The metadata database is based on the GCMD DIF standard because GCMD have already defined large lists of keywords for encoding the physical quantities, the data centres, *etc.* Use of these keyword lists provides a simple and efficient way for users to make unambiguous searches of the database in order to locate the data they want. GCMD also has a large set of sensibly defined metadata fields based on years of experience of serving metadata, from which we have scavenged a subset for the HR-DDS.

The HR-DDS data files themselves have been chosen to follow the Climate and Forecast netCDF conventions because these conventions provide a practical standard for storing oceanographic data, and have already been adopted for the Data Sharing Pilot project within GODAE.

The attributes of the netCDF files are also metadata, and since they follow the CF conventions, they are somewhat in conflict with the HR-DDS metadata database standard. To a certain extent, this is reasonable, since the database metadata is intended to help users search for useful data sets, while the netCDF attributes are to help them actually use the data, i.e. these two different types of metadata serve two slightly different purposes. Also, the data files should only contain information about the data itself, and not external information such as the data centre name or access constraints, which can easily change. However, the adoption of this hybrid of GCMD DIF and netCDF CF metadata is uncomfortable, as there isn't a one-to-one mapping between all the field definitions in the two standards.

This is a first attempt to set up the HR-DDS concept, and so we have no experience of how well the users and data providers will interact with it. Later on the system will change in the light of that experience, so we leave questions on how to resolve this GCMD DIF versus netCDF CF conflict until then. Perhaps we'll one day know how to write a Climate and Forecast metadata standard to accompany the netCDF CF standard.

3.7 Using the HR-DDS

3.7.1 How does a user use the HR-DDS?

Often, collaboration between groups of researchers is frustrated by the technical difficulties of sharing datasets. Different groups use different data formats and analysis packages, and cannot easily combine their data. Network communications problems impede the collaborative efforts of geographically scattered groups but more importantly, centralized data repositories provide a poor solution to the support of dynamically changing datasets such as that envisaged in the GHRSST-PP DDS.

The following "use case" scenarios explain how the HR-DDS system is used from a practical point of view. User *A.N. Other* wants to check under what meteorological conditions the microwave radiometer SSTs differ from the analysed AVHRR SSTs in the Indian Ocean.

1. User searches the GHRSST-PP main web metadata database for all HR-DDS SST datasets from AVHRR and AMSR, plus NCEP met analyses over a lat-lon rectangle containing the Indian Ocean for year 2000.
2. The GHRSST-PP web database will return a page listing the set of matching metadata records, with hyperlinks pointing directly to each data file. The various data files would probably be produced by different institutes, and hence be located at different internet sites.
3. The user could then:
   - Download individual DDS granules using the hyperlinks provided, and work on the files locally.
   - Request to download *all* the matching data files in one go.
   - Directly interrogate the data via a DODS interface.

3.7.2 How does the data provider populate the DDS?

As currently envisioned, HR-DDS data will be extracted in real-time as L1 data are initially generated by data providing agencies. The emphasis is to facilitate generation of HR-DDS data as much as possible. New data will be received in real-time via dedicated push data feeds and automatically archived at HR-DDS data archive centres on a regular basis. A HR-DDS metadata record for every HR-DDS data granule (i.e., a satellite image, or in situ measurement record) will be generated and submitted to the HR-DDS system via the Internet for ingestion into the HR-DDS metadata repository database. The generation of accurate and complete metadata records is vital to the operational functionality of the HR-DDS system as metadata provide the only searchable link to the data themselves. Considering the huge number of individual data granules within the HR-DDS (e.g., for all HR-

DDS sites shown in Figure 2, over 160,000 HR-DDS data granules were derived from the AVHRR sensor alone in 1999), it is vital that metadata records are available.

3.7.3 What is the role of the GHRSST-PP Project Office?

The role of the GHRSST-PP Project Office is threefold:

- Review potential new HR-DDS data sources and oversee implementation of the data flow to GHRSST-PP.
- Quality control of the format and integrity of HR-DDS data files and metadata before ingestion into the HR-DDS data and metadata repositories.
- Maintenance of the metadata valid keyword lists, which will expand as new data types become available and existing gaps are plugged.

Detailed Implementation Model (Not complete)

The following sections describe the implementation and operation of the GHRSST-PP HR-DDS system. The system should be operating and have been tested prior to the start of the GHRSST-PP demonstration phase which will begin in June 2003.

3.8 Objective

To implement, test, operate and maintain the GHRSST-PP HR-DDS as a distributed data resource. Initially, a pilot HR-DDS system will be developed and installed. Following a period of system acceptance tests, this system can then be used at other GHRSST-PP HR-DDS sites.

3.9 Description

A pilot HR-DDS system will be implemented at the Joint Research Centre Inland and Marine Waters unit during the GHRSST-PP preparation phase. This will comprise of the following:

i. A linux workstation
ii. A 200Gb storage disk. For FTP access a standard directory structure should be defined using that conforms to the following format:

    /pub/hrdds/<dds_name>/<sensor>/<data_type>/<date_time_spec>

    e.g. /pub/hrdds/ghr001/atsr2/sst/19990101

iii. A DODs server providing external JRC user access to the HR-DDS system
iv. A secure ftp server allowing easy data access
v. A metadata repository built using the MySQL database system
vi. A graphical user interface providing WWW access to the HR-DDS
vii. A set of data ingestions scripts to automatically ingest and quality control HR-DDS metadata records
viii. The ability to send an e-mail to data providers if metadata/data ingestion into the system raises an error

Acceptance tests will include the following:

i. Checking the HR-DDS for internal consistency and reliability by extensive data searches and cross checking of search results.
ii. That the system operates at an acceptable speed
iii. That data are successfully ingested consistently and automatically

iv. That an appropriate e-mail message is sent to the data provider (based on the information contained in the Data_Set_Record)
v. That the user interface meets user needs

Following acceptance, the pilot HR-DDS system can then be mirrored at other GHRSST-PP HR-DDS sites that provide identical functionality. A master GHRSST-PP HR-DDS metadata repository will be held at the JPL PO.DAAC.

3.9.1 Definition of parameters (Input, output, internal, temporary, etc.)

Potential HR-DDS user institutions include:
- Southampton Oceanography Centre, Southampton, UK
- Remote Sensing Systems, Santa Rosa, USA
- University of Tohoku, Tohoku, Japan
- NASDA EORC, Tokyo, Japan
- US-GODAE, Monterrey, USA
- University of Colorado, Boulder, USA
- NOAA USA
- Others to be determined as the project progresses

Potential Master Metadata repository mirror sites:
- European Commission Joint Research Centre, Ispra, Italy
- PO.DAAC, Jet Propulsion Laboratory, Pasadena, USA
- IFREMER, Brest, France
- University of Tohoku, Tohoku, Japan

Potential HR-DDS Data providers include the following:

• European Space Agency	ENVISAT AATSR, RA-2
• EUMETSAT O&SI SAF	MSG, GOES-E
• Remote Sensing Systems	AMSR,AMSR-E, TRMM TMI, SSM/I
• NASDA	AMSR,AMSR-E, TRMM TMI, GLI, GMS
• NAVOCEAN	GOES-W,GOES-E, AVHRR-GAC
• AOML	TAO/PIRATA, drifting buoy
• SOC	In situ radiometer data
• JMA	In situ buoy
• UK Met. Office	In situ buoy
• Various	Research cruise data

Table 10 provides a summary description of the desirable data sets to be included in the HR-DDS system.

Table 10. Estimated data volume and frequency for GHRSST-PP HR-DDS 2x2° data sets.

Data set	L1b (multi-ch)	SST product only	Frequency (per day)	Total daily volume (uncompressed)	Comments
AVHRR GAC	500Kb		2 x daily		(~100Kb compressed)
AVHRR LAC 1km	4.5Mb		2 x Daily		(~1Mb compressed)
MODIS-terra					
MODIS aqua					
GLI					
AATSR 1km					
AATSR 17 km					
AATSR 0.5 degree			Daily		
AMSR 25 km			2 x daily		
AMSR-E 25 km			2 x daily		
TMI (25 km, 8bit)			Daily		
MSG (~4km)			8 x daily		
GOES (~4km)			8 x daily		
GMS (~4km)			8 x daily		
Buoy & ship			GTS		
SSM/I (8bit, wind,sea ice)			Daily		
Merged GHRSST-pp products			6 hourly		
Analyzed GHRSST-pp products			12 hourly		
Reanalysis GHRSST-pp products			12 hourly		
TAO array					
PIRATA array					
Drifters					
Research cruises					
Other buoy (Met office, JMA etc.)					

3.9.2 Data flow diagram

Nice piccy of servers and locations
Nice piccy of data flow within the DDS

3.9.3 Error handling

Er….

3.9.4 Implementation recommendations

The initial pilot HR-DDS system should be operational and tested before other HR-DDS systems are installed and operated.

3.9.5 Critical parameter data list

The following are considered critical parameters to be included in the HR-DDS system:

- NOAA AVHRR (SST and if possible, brightness temperature)
- AATSR (SST and if possible, brightness temperature)
- MSG (SST and if possible, brightness temperature)
- GOES-E (Specific Channels)
- GOES-W (Specific Channels)
- GMS (Specific channels)
- AMSR (SST, 10 meter Surface Wind Speed, Columnar Water Vapor, Cloud Liquid Water)
- AMSR-E (SST, 10 meter Surface Wind Speed, Columnar Water Vapor, Cloud Liquid Water)
- SSM/I (10 meter Surface Wind Speed, Columnar Water Vapor, Cloud Liquid Water)
- TRMM TMI (SST, 10 meter Surface Wind Speed, Columnar Water Vapor, Cloud Liquid Water)
- TAO (SST, wind speed)
- PIRATA (SST, wind speed)
- Met Office buoy observations (SST, wind speed)

3.10 Estimated budget

Table 11. GHRSST-PP HR-DDS staff costs.

STAFF COSTS	2002	2003	2004	2005	Total
Project coordinator					
Local HR-DDS Coordinators					
TOTAL					

Table 12. GHRSST-PP HR-DDS hardware infrastructure costs.

HARDWARE INFRASTRUCTURE COSTS	2002	2003	2004	2005	Total
Linux PC					
RAID disk storage (300Gb					
Installation of software					
Maintenance					
TOTAL					

Table 13. GHRSST-PP software infrastructure costs.

SOFTWARE INFRASTRUCTURE COSTS	2002	2003	2004	2005	Total
DODS-GrADS server installation					
Metadata database development and installation					
TOTAL					

Table 14. GHRSST-PP other costs.

OTHER COSTS	2002	2003	2004	2005	Total
Workshop					
Meetings					
TOTAL					

4 References

5 GHRSST-PP HR-DDS contacts

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Add others Emery Kawamura LeBorgen Robinson Gentemann

6 Annex 1 Specification of v2.0 GHRSST-PP high Resolution Diagnostic Data Set Sites

```
############################################################
#
# GODAE/GHRSST-PP Diagnostic Data Set (DDS) coordinates
#
# VERSION 2
#
# Maintained by: Simon Pinnock & Craig Donlon
#
############################################################
#
# Revision History
#
# v2.0, 1-Jul-2002, SP
# Created
#
# v2.1, 1-Aug-2002, SP
# Updated longitude of Qinghai Hu Lake DDS.
#
# v2.2, 26-Aug-2002, SP
# Corrected mistake where both CAN-46147 and CAN-44141 were labelled as "can001"
#
############################################################
#
#
# Location (GCMD location_valid > GHRSST short name), lat , lon , y-size, x-size, comment
#
Atlantic Ocean > ghr001, 35 , -15 , 2.0 , 2.0 , Madeira
GHRSST , ghr002 , 50 , -30 , 2.0 , 2.0 , N Ntlantic
GHRSST , ghr003 , 30 , -30 , 2.0 , 2.0 , Central N Sub-tropical Atlantic
GHRSST , ghr004 , -20 , -30 , 2.0 , 2.0 , Central S Sub-tropical Atlantic
GHRSST , ghr005 , -62.5 , -30 , 25.0 , 5.0 , Weddel Sea (ice edge)
GHRSST , ghr006 , 50 , -45 , 2.0 , 2.0 , W N Atlantic
GHRSST , ghr007 , 30 , -50 , 2.0 , 2.0 , W Atlantic
GHRSST , ghr008 , -38 , -45 , 2.0 , 2.0 , Argentina coast
GHRSST , ghr009 , 72.5 , -65 , 5.0 , 5.0 , Baffin Bay
GHRSST , ghr010 , -62.5 , -70 , 15.0 , 5.0 , Drake passage (ice edge)
GHRSST , ghr011 , -30 , -74 , 2.0 , 2.0 , Chile
GHRSST , ghr012 , -45 , -90 , 2.0 , 2.0 , Pacific-Antarctic basin
GHRSST , ghr013 , -25 , -105 , 2.0 , 2.0 , Easter Island
GHRSST , ghr014 , -45 , -110 , 2.0 , 2.0 , Pacific Antarctic Ridge
GHRSST , ghr015 , -67.5 , -110 , 15.0 , 5.0 , Amudsen Sea (ice edge)
GHRSST , ghr016 , -37 , -130 , 2.0 , 2.0 , Pitcairn Isaland S Pacific
GHRSST , ghr017 , 30 , -150 , 2.0 , 2.0 , Central N Pacific
GHRSST , ghr018 , -37 , -150 , 2.0 , 2.0 , S Central Pacific
GHRSST , ghr019 , -65 , -150 , 20.0 , 5.0 , W Ross Sea (ice edge)
GHRSST , ghr020 , 70 , -170 , 5.0 , 5.0 , Chukchi Sea
GHRSST , ghr021 , 40 , -170 , 2.0 , 2.0 , Alutian Islands
GHRSST , ghr022 , -45 , -170 , 2.0 , 2.0 , Kermadec trench, S Pacific
GHRSST , ghr023 , 50 , 170 , 2.0 , 2.0 , W Alutian Islands
GHRSST , ghr024 , 30 , 170 , 2.0 , 2.0 , NW Pacific
GHRSST , ghr025 , -30 , 170 , 2.0 , 2.0 , Norfolk Is. S Pacific
GHRSST , ghr026 , -65 , 170 , 20.0 , 5.0 , E Ross Sea (ice edge)
GHRSST , ghr027 , 55 , 150 , 2.0 , 2.0 , Sea of Okhotsk
GHRSST , ghr028 , -15 , 150 , 2.0 , 2.0 , Coral Sea
GHRSST , ghr029 , -45 , 150 , 2.0 , 2.0 , S Tasman Ridge
GHRSST , ghr030 , -61 , 130 , 12.0 , 5.0 , S Ocean (ice edge)
GHRSST , ghr031 , 7 , 110 , 2.0 , 2.0 , S China Sea
GHRSST , ghr032 , -15 , 110 , 2.0 , 2.0 , Java Trench
GHRSST , ghr033 , -45 , 110 , 2.0 , 2.0 , Eastern S Ocean
GHRSST , ghr034 , 15 , 90 , 2.0 , 2.0 , Bay of Bengal
GHRSST , ghr035 , -30 , 90 , 2.0 , 2.0 , Central S. Ocean
GHRSST , ghr036 , -45 , 90 , 2.0 , 2.0 , Central S. Ocean
```

```
GHRSST , ghr037 , -61 , 90 , 12.0 , 5.0 , S Ocean (ice edge)
GHRSST , ghr038 , 20 , 65 , 2.0 , 2.0 , Arabian Sea
GHRSST , ghr039 , 10 , 55 , 2.0 , 2.0 , Somali Jet
GHRSST , ghr040 , -10 , 70 , 2.0 , 2.0 , Indian Ocean
GHRSST , ghr041 , -30 , 70 , 2.0 , 2.0 , S Indian Ocean
GHRSST , ghr042 , -45 , 70 , 2.0 , 2.0 , Kerguelen Is. S Ocean
GHRSST , ghr043 , -5 , 50 , 2.0 , 2.0 , Somali Basin
GHRSST , ghr044 , -30 , 50 , 2.0 , 2.0 , Mauritius Basin
GHRSST , ghr045 , -45 , 50 , 2.0 , 2.0 , S Indian Ocean
GHRSST , ghr046 , -61 , 50 , 12.0 , 5.0 , S Indian Ocean (ice edge)
GHRSST , ghr047 , -45 , 30 , 2.0 , 2.0 , Agulhas Basin
GHRSST , ghr048 , 36 , 19 , 2.0 , 2.0 , Meditteranean
GHRSST , ghr049 , -30 , 0 , 2.0 , 2.0 , SE Atlantic
GHRSST , ghr050 , -60 , 10 , 20.0 , 5.0 , SE Atlantic (ice edge)
GHRSST , ghr051 , 60.0 , -55.0 , 5.0 , 5.0 , Davis Strait
GHRSST , ghr052 , 60.0 , -30.0 , 2.0 , 2.0 , Denmark Strait
GHRSST , ghr053 , 43.0 , 31.5 , 2.0 , 2.0 , Black Sea
GHRSST , ghr054 , 42.5 , 50.0 , 2.0 , 2.0 , Caspian Sea
GHRSST , ghr055 , 39.2 ,-120.0 , 1.0 , 1.0 , Lake Tahoe, USA
GHRSST , ghr056 , 36.8 , 100.2 , 1.0 , 1.5 , Qinghai Hu Lake, China
GHRSST , ghr057 , 17.5 , 40.0 , 2.0 , 2.0 , Red Sea
GHRSST , ghr058 , -15.0 , -80.0 , 2.0 , 2.0 , Peru current
GHRSST , ghr059 , -20.0 , -85.0 , 2.0 , 2.0 , IMET/EPIC mooring under stratus cloud
GHRSST , ghr060 , 40.0 , 6.0 , 2.0 , 2.0 , Western Meiterranean
GHRSST , ghr061 , -20.0 , 150.0 , 2.0 , 2.0 , Great Barrier Reef
GHRSST , ghr062 , 59.0 , -86.0 , 2.0 , 2.0 , Hudson Bay
GHRSST , ghr063 , 75.0 , 0.0 , 12.0 , 5.0 , Greenland Sea and ice edge
GHRSST , ghr064 , 25.0 , -81.0 , 2.0 , 2.0 , Florida Keys (C-MAN sites)
GHRSST , ghr065 , -40.0 , -20.0 , 2.0 , 2.0 , S Atlantic
GHRSST , ghr066 , 75.0 , 40.0 , 5.0 , 5.0 , Barents Sea
GHRSST , ghr067 , 74.0 , 130.0 , 5.0 , 5.0 , Laptev Sea
GHRSST , ghr068 , -20.0 ,-140.0 , 2.0 , 2.0 , South Pacific
#
# DDSs located over moored buoys
#
NDBC-46035 , ndb051 , 57.08 ,-177.71 , 2.0 , 2.0 , Bering Sea
TAO , tao038 , 8.0 ,-170.0 , 2.0 , 2.0 , (Aug 1992)
TAO , tao044 , -8.0 ,-170.0 , 2.0 , 2.0 , (Aug 1992)
TAO , tao041 , 0.0 ,-170.0 , 2.0 , 2.0 , (May 1998)
NDBC-46066 , ndb063 , 52.65 ,-155.00 , 2.0 , 2.0 , Kodiak
TAO , tao031 , 8.0 ,-155.0 , 2.0 , 2.0 , (Aug 1992)
TAO , tao037 , -8.0 ,-155.0 , 2.0 , 2.0 , (Mar 1992)
NDBC-46006 , ndb039 , 40.84 ,-137.49 , 2.0 , 2.0 , SW. Astoria
TAO , tao018 , 8.0 ,-125.0 , 2.0 , 2.0 , (Oct 1992)
TAO , tao021 , 0.0 ,-125.0 , 2.0 , 2.0 , (Oct 1983)
TAO , tao024 , -8.0 ,-125.0 , 2.0 , 2.0 , (Sep 1992)
TAO , tao025 , 9.0 ,-140.0 , 2.0 , 2.0 , (May 1988)
TAO , tao028 , 0.0 ,-140.0 , 2.0 , 2.0 , (Apr 1983)
TAO , tao030 , -5.0 ,-140.0 , 2.0 , 2.0 , (Oct 1990)
TAO , tao011 , 8.0 ,-110.0 , 2.0 , 2.0 , (Oct 1991)
TAO , tao014 , 0.0 ,-110.0 , 2.0 , 2.0 , (Jan 1979)
TAO , tao017 , -8.0 ,-110.0 , 2.0 , 2.0 , (Nov 1985)
TAO , tao001 , 12.0 , -95.0 , 2.0 , 2.0 , (Dec 1999)
TAO , tao007 , 0.0 , -95.0 , 2.0 , 2.0 , (Jul 1981, inactive □83-□92)
TAO , tao010 , -8.0 , -95.0 , 2.0 , 2.0 , (Aug 1994)
CAN-46147 , can001 , 51.83 ,-131.22 , 2.0 , 2.0 , Vancouver
MF-41100 , mfr001 , 15.9 , -57.9 , 2.0 , 2.0 , Antilles (Meteo France)
CAN-44141 , can002 , 42.10 , -56.22 , 2.0 , 2.0 , Gulf Stream
EGOS-62081 , ego003 , 51.0 , -13.3 , 2.0 , 2.0 , Celtic Sea
PIRATA-Reggae , pir007 , 15.0 , -38.0 , 2.0 , 2.0 , (Jan 1998)
PIRATA-Forro , pir008 , 12.0 , -38.0 , 2.0 , 2.0 , (Feb 1999)
PIRATA-Lambada , pir009 , 8.0 , -38.0 , 2.0 , 2.0 , (Jan 1998)
PIRATA-Frevo , pir010 , 4.0 , -38.0 , 2.0 , 2.0 , (Feb 1999)
PIRATA-Samba , pir006 , 0.0 , -35.0 , 2.0 , 2.0 , (Jan 1998)
PIRATA-Jazz , pir005 , 0.0 , -23.0 , 2.0 , 2.0 , (Mar 1999)
PIRATA-Soul , pir001 , 0.0 , 0.0 , 2.0 , 2.0 , (Feb 1998)
```

PIRATA-Java , pir002 , 0.0 , -10.0 , 2.0 , 2.0 , (Sep 1997)
PIRATA-Valse , pir003 , -6.0 , -10.0 , 2.0 , 2.0 , (Mar 2000)
PIRATA-Gavotte , pir004 , -10.0 , -10.0 , 2.0 , 2.0 , (Sep 1997)
UKMO-63117 , ukm004 , 58.0 , 1.10 , 2.0 , 2.0 , North Sea
TAO/TRITON , tao073 , -5.0 , 95.0 , 2.0 , 2.0 , (26 Oct 2001)
NDBC-45001 , ndb027 , 48.06 , -87.78 , 2.0 , 2.0 , Mid Lake Superior, USA
TAO/TRITON , tao069 , 8.0 , 137.0 , 2.0 , 2.0 , (28 Sep 2001)
TAO/TRITON , tao071 , 0.0 , 138.0 , 2.0 , 2.0 , (03 Oct 2001)
TAO/TRITON , tao065 , 5.0 , 147.0 , 2.0 , 2.0 , (Feb 1990; Triton from 1999)
TAO/TRITON , tao067 , 0.0 , 147.0 , 2.0 , 2.0 , (Apr 1994; Triton from 1999)
TAO/TRITON , tao059 , 8.0 , 156.0 , 2.0 , 2.0 , (Dec 1994; Triton from 1999)
TAO/TRITON , tao062 , 0.0 , 156.0 , 2.0 , 2.0 , (Jul 1995; Triton from 1999)
TAO/TRITON , tao064 , -5.0 , 156.0 , 2.0 , 2.0 , (Aug 1991; Triton from 1999)
TAO , tao055 , 0.0 , 165.0 , 2.0 , 2.0 , (Jan 1986)
TAO , tao052 , 8.0 , 165.0 , 2.0 , 2.0 , (Jul 1989)
TAO , tao058 , -8.0 , 165.0 , 2.0 , 2.0 , (Aug 1991)
TAO , tao045 , 8.0 , 180.0 , 2.0 , 2.0 , (Nov 1993)
TAO , tao048 , 0.0 , 180.0 , 2.0 , 2.0 , (Mar 1993)
TAO , tao051 , -8.0 , 180.0 , 2.0 , 2.0 , (Nov 1993)
NDBC-42002 , ndb008 , 25.17 , -94.42 , 2.0 , 2.0 , Western Gulf
#
SIMBIOS □□Diagnostic Data Set Sites□□ locations from sites.xls table from
http://simbios.gsfc.nasa.gov/Info/STM2001/Sites.html
Note: XLS table site coordinates differ significantly from those listed on
the above web page (which is correct???)
The Ishigaki site is listed twice (2nd time as □□YBOM replacement□□) in the XLS file.
#
SIMBIOS-MOBY , sim001 , 20.8 ,-157.20 , 2.0 , 2.0 , Hawaii
SIMBIOS-BATS/BTM , sim002 , 32.0 , -64.50 , 2.0 , 2.0 , Bermuda
SIMBIOS-CALCOFI , sim003 , 29.85 ,-123.59 , 2.0 , 2.0 , California
SIMBIOS-EqPAC , sim004 , 0.0 ,-155.00 , 2.0 , 2.0 , Eastern Equ Pacific
SIMBIOS-HOT , sim005 , 22.75 ,-158.00 , 2.0 , 2.0 , Hawaii
SIMBIOS-Ishigaki , sim006 , 24.39 , 123.27 , 2.0 , 2.0 , East China Sea
SIMBIOS-Ligurian_Sea , sim007 , 43.37 , 7.90 , 2.0 , 2.0 , Mediterranean
SIMBIOS-Lower_Chesapeake_Bay , sim008 , 37.40 , -76.13 , 2.0 , 2.0 , Virginia
SIMBIOS-Monterey_Bay , sim009 , 36.75 ,-122.42 , 2.0 , 2.0 , Monterey
SIMBIOS-Plymbody , sim010 , 50.2 , -4.10 , 2.0 , 2.0 , English Channel
SIMBIOS-Venice_Tower , sim011 , 45.31 , 12.60 , 2.0 , 2.0 , Northern Adriatic
SIMBIOS-Station_H , sim012 , 41.5 , 145.78 , 2.0 , 2.0 , Japan East Coast
SIMBIOS-Cariaco_Basin , sim013 , 10.5 , -64.66 , 2.0 , 2.0 , Venezuela
SIMBIOS-Kashidoo , sim014 , 4.95 , 73.45 , 2.0 , 2.0 , Maldives Islands
SIMBIOS-Korean , sim015 , 32.0 , 125.00 , 2.0 , 2.0 , East China Sea
SIMBIOS-LEO_15 , sim016 , 39.3 , -74.25 , 2.0 , 2.0 , New Jersey
SIMBIOS-Plumes_and_Blumes , sim017 , 34.25 ,-119.92 , 2.0 , 2.0 , off Santa Barbara CA
SIMBIOS-Scotian_Prince_Route , sim018 , 43.00 , -69.00 , 2.0 , 2.0 , Gulf of Maine
SIMBIOS-NOAA-GOM , sim019 , 29.50 , -87.50 , 2.0 , 2.0 , Northern Gulf of Mexico
SIMBIOS-NOAA-NC , sim020 , 35.00 , -76.50 , 2.0 , 2.0 , off North Carolina
SIMBIOS-Rottnest_Island , sim021 , -31.80 , 115.30 , 2.0 , 2.0 , off Western Australia
#
Other proposed SIMBIOS sites:
#
SIMBIOS-Arm_1 , sim022 , 0.00 , 168.00 , 2.0 , 2.0 , Nauru Island
SIMBIOS-Arm_2 , sim023 , 25.00 , 148.00 , 2.0 , 2.0 , Manus Island
SIMBIOS-NW_Afr_Upwell , sim025 , 21.00 , -17.50 , 2.0 , 2.0 , Morocco
SIMBIOS-Alberon_Gyre , sim026 , 33.00 , 32.50 , 2.0 , 2.0 , Eastern Mediterranean
SIMBIOS-Helgoland , sim027 , 54.00 , 9.00 , 2.0 , 2.0 , North Sea
SIMBIOS-Nordic , sim028 , 55.00 , 19.30 , 2.0 , 2.0 , Baltic Sea
SIMBIOS-Luderitz_Upwell , sim029 , -26.00 , 14.50 , 2.0 , 2.0 , Namibia
SIMBIOS-Philippine_Sea , sim030 , 17.00 , 133.00 , 2.0 , 2.0 , Southeast Asia
SIMBIOS-Cook_Islands , sim031 , -20.00 ,-163.00 , 2.0 , 2.0 , Australia

7 Annex 2 Reference tables for Projection metadata

7.1 Projection_Type controlled list

```
############################################################
#
# GODAE/GHRSST-PP Diagnostic Data Set (DDS) Projection_Type controlled list
#
# VERSION 1
#
# Maintained by: Craig Donlon
#
############################################################
#
# Revision History
#
# v1.0, 14-10-2002
# Created
#
#
##################################################
#
#
#Code, Short Description, Long Description
#
1, MERC, Mercator
2, TMERC, Transverse Mercator
3, OMERC, Oblique Mercator
4, CC, Central Cylindrical
5, TCC, Transverse Central Cylindrical
6, MILL, Miller Cylindrical
7, CEA, Lambert Cylindrical Equal Area
8, GALL, Gall (Stereographic)
9, TCEA, Transverse Cylindrical Equal Area
10, EQC, Equidistant Cylindrical
11, CASS, Cassini
12, SINU, Sinusoidal
13, MOLL, Mollweide
14, ROBIN, Robinson
15, ECK1, Eckert I
16, ECK2, Eckert II
17, ECK3, Eckert III
18, ECK4, Eckert IV
19, ECK5, Eckert V
20, ECK6, Eckert VI
21, GOODE, Goode Homolosine
22, HATAEA, Hatano Asymmetrical Equal-Area
23, LOXIM, Loximuthal
24, MBTFPP, McBride-Thomas Flat-Polar Parabolic
25, MBTFPQ, McBride-Thomas Flat-Polar Quartic
26, MBTFPS, McBride-Thomas Flat-Polar Sinusoidal
27, PUTP2, Putnins P2
28, PUTP5, Putnins P5
29, QUAU, Quartic Authalic
30, WINK1, Winkel 1
31, BOGGS, Boggs Eumorphic
32, COLLG, Collignon
33, LCC, Lambert Conformal Conic
34, EQDC, Equidistant Conic
35, PCONIC, Perspective Conic
36, AEA, Albers (Conic) Equal Area
37, LEAC, Lambert Equal Area
38, BIPC, Bipolar Oblique Conic Conformal
39, POLY, Polyconic (American)
40, RPOLY, Rectangular Polyconic
```

41, BONNE, Bonne
42, STERE, Stereographic
43, UPS, Universal Polar Stereographic
44, GNOM, Gnomonic
45, ORTHO, Orthographic
46, AIRY, Airy
47, NSPER, Near-Sided Perspective
48, LAEA, Lambert Azimuthal Equal Area
49, AEQD, Azimuthal Equidistant
50, HAMMER, Hammer
51, WAG7, Wagner VII
52, AITOFF, Aitoff
53, WINTRI, Winkel Tripel
54, AUGUST, August Epicycloidal
55, BACON, Bacon Globular
56, NICOL, Nicolosi Globular
57, FOURN, Fournier Globular I
58, APIAN, Apian Globular I
59, EISEN, Eisenlohr
60, ORTEL, Ortelius Oval
61, VANDG, Van der Grinten I
62, VANDG2, Van der Grinten II
63, VANDG3, Van der Grinten III
64, VANDG4, Van der Grinten IV
65, LAGRNG, Lagrange
66, LONGLAT, Long/Lat
67, UTM 1 N, Universal Transverse Mercator + Zone + Lat
68, UTM 2 N, Universal Transverse Mercator + Zone + Lat
69, UTM 3 N, Universal Transverse Mercator + Zone + Lat
70, UTM 4 N, Universal Transverse Mercator + Zone + Lat
71, UTM 5 N, Universal Transverse Mercator + Zone + Lat
72, UTM 6 N, Universal Transverse Mercator + Zone + Lat
73, UTM 7 N, Universal Transverse Mercator + Zone + Lat
74, UTM 8 N, Universal Transverse Mercator + Zone + Lat
75, UTM 9 N, Universal Transverse Mercator + Zone + Lat
76, UTM 10 N, Universal Transverse Mercator + Zone + Lat
77, UTM 11 N, Universal Transverse Mercator + Zone + Lat
78, UTM 12 N, Universal Transverse Mercator + Zone + Lat
79, UTM 13 N, Universal Transverse Mercator + Zone + Lat
80, UTM 14 N, Universal Transverse Mercator + Zone + Lat
81, UTM 15 N, Universal Transverse Mercator + Zone + Lat
82, UTM 16 N, Universal Transverse Mercator + Zone + Lat
83, UTM 17 N, Universal Transverse Mercator + Zone + Lat
84, UTM 18 N, Universal Transverse Mercator + Zone + Lat
85, UTM 19 N, Universal Transverse Mercator + Zone + Lat
86, UTM 20 N, Universal Transverse Mercator + Zone + Lat
87, UTM 21 N, Universal Transverse Mercator + Zone + Lat
88, UTM 22 N, Universal Transverse Mercator + Zone + Lat
89, UTM 23 N, Universal Transverse Mercator + Zone + Lat
90, UTM 24 N, Universal Transverse Mercator + Zone + Lat
91, UTM 25 N, Universal Transverse Mercator + Zone + Lat
92, UTM 26 N, Universal Transverse Mercator + Zone + Lat
93, UTM 27 N, Universal Transverse Mercator + Zone + Lat
94, UTM 28 N, Universal Transverse Mercator + Zone + Lat
95, UTM 29 N, Universal Transverse Mercator + Zone + Lat
96, UTM 30 N, Universal Transverse Mercator + Zone + Lat
97, UTM 31 N, Universal Transverse Mercator + Zone + Lat
98, UTM 32 N, Universal Transverse Mercator + Zone + Lat
99, UTM 33 N, Universal Transverse Mercator + Zone + Lat
100, UTM 34 N Universal Transverse Mercator + Zone + Lat
101, UTM 35 N, Universal Transverse Mercator + Zone + Lat
102, UTM 36 N, Universal Transverse Mercator + Zone + Lat
103, UTM 37 N, Universal Transverse Mercator + Zone + Lat
104, UTM 38 N, Universal Transverse Mercator + Zone + Lat
105, UTM 39 N, Universal Transverse Mercator + Zone + Lat
106, UTM 40 N, Universal Transverse Mercator + Zone + Lat

107, UTM 41 N, Universal Transverse Mercator + Zone + Lat
108, UTM 42 N, Universal Transverse Mercator + Zone + Lat
109, UTM 43 N, Universal Transverse Mercator + Zone + Lat
110, UTM 44 N, Universal Transverse Mercator + Zone + Lat
111, UTM 45 N, Universal Transverse Mercator + Zone + Lat
112, UTM 46 N, Universal Transverse Mercator + Zone + Lat
113, UTM 47 N, Universal Transverse Mercator + Zone + Lat
114, UTM 48 N, Universal Transverse Mercator + Zone + Lat
115, UTM 49 N, Universal Transverse Mercator + Zone + Lat
116, UTM 50 N, Universal Transverse Mercator + Zone + Lat
117, UTM 51 N, Universal Transverse Mercator + Zone + Lat
118, UTM 52 N, Universal Transverse Mercator + Zone + Lat
119, UTM 53 N, Universal Transverse Mercator + Zone + Lat
120, UTM 54 N, Universal Transverse Mercator + Zone + Lat
121, UTM 55 N, Universal Transverse Mercator + Zone + Lat
122, UTM 56 N, Universal Transverse Mercator + Zone + Lat
123, UTM 57 N, Universal Transverse Mercator + Zone + Lat
124, UTM 58 N, Universal Transverse Mercator + Zone + Lat
125, UTM 59 N, Universal Transverse Mercator + Zone + Lat
126, UTM 60 N, Universal Transverse Mercator + Zone + Lat
127, UTM 1 S, Universal Transverse Mercator + Zone + Lat
128, UTM 2 S, Universal Transverse Mercator + Zone + Lat
129, UTM 3 S, Universal Transverse Mercator + Zone + Lat
130, UTM 4 S, Universal Transverse Mercator + Zone + Lat
131, UTM 5 S, Universal Transverse Mercator + Zone + Lat
132, UTM 6 S, Universal Transverse Mercator + Zone + Lat
133, UTM 7 S, Universal Transverse Mercator + Zone + Lat
134, UTM 8 S, Universal Transverse Mercator + Zone + Lat
135, UTM 9 S, Universal Transverse Mercator + Zone + Lat
136, UTM 10 S, Universal Transverse Mercator + Zone + Lat
137, UTM 11 S, Universal Transverse Mercator + Zone + Lat
138, UTM 12 S, Universal Transverse Mercator + Zone + Lat
139, UTM 13 S, Universal Transverse Mercator + Zone + Lat
140, UTM 14 S, Universal Transverse Mercator + Zone + Lat
141, UTM 15 S, Universal Transverse Mercator + Zone + Lat
142, UTM 16 S, Universal Transverse Mercator + Zone + Lat
143, UTM 17 S, Universal Transverse Mercator + Zone + Lat
144, UTM 18 S, Universal Transverse Mercator + Zone + Lat
145, UTM 19 S, Universal Transverse Mercator + Zone + Lat
146, UTM 20 S, Universal Transverse Mercator + Zone + Lat
147, UTM 21 S, Universal Transverse Mercator + Zone + Lat
148, UTM 22 S, Universal Transverse Mercator + Zone + Lat
149, UTM 23 S, Universal Transverse Mercator + Zone + Lat
150, UTM 24 S, Universal Transverse Mercator + Zone + Lat
151, UTM 25 S, Universal Transverse Mercator + Zone + Lat
152, UTM 26 S ,Universal Transverse Mercator + Zone + Lat
153, UTM 27 S ,Universal Transverse Mercator + Zone + Lat
154, UTM 28 S ,,Universal Transverse Mercator + Zone + Lat
155, UTM 29 S, Universal Transverse Mercator + Zone + Lat
156, UTM 30 S, Universal Transverse Mercator + Zone + Lat
157, UTM 31 S ,Universal Transverse Mercator + Zone + Lat
158, UTM 32 S, Universal Transverse Mercator + Zone + Lat
159, UTM 33 S, Universal Transverse Mercator + Zone + Lat
160, UTM 34 S, Universal Transverse Mercator + Zone + Lat
161, UTM 35 S, Universal Transverse Mercator + Zone + Lat
162, UTM 36 S, Universal Transverse Mercator + Zone + Lat
163, UTM 37 S, Universal Transverse Mercator + Zone + Lat
164, UTM 38 S, Universal Transverse Mercator + Zone + Lat
165, UTM 39 S, Universal Transverse Mercator + Zone + Lat
166, UTM 40 S, Universal Transverse Mercator + Zone + Lat
167, UTM 41 S, Universal Transverse Mercator + Zone + Lat
168, UTM 42 S, Universal Transverse Mercator + Zone + Lat
169, UTM 43 S, Universal Transverse Mercator + Zone + Lat
170, UTM 44 S, Universal Transverse Mercator + Zone + Lat
171, UTM 45 S, Universal Transverse Mercator + Zone + Lat
172, UTM 46 S, Universal Transverse Mercator + Zone + Lat

173, UTM 47 S, Universal Transverse Mercator + Zone + Lat
174, UTM 48 S, Universal Transverse Mercator + Zone + Lat
175, UTM 49 S, Universal Transverse Mercator + Zone + Lat
176, UTM 50 S, Universal Transverse Mercator + Zone + Lat
177, UTM 51 S, Universal Transverse Mercator + Zone + Lat
178, UTM 52 S, Universal Transverse Mercator + Zone + Lat
179, UTM 53 S, Universal Transverse Mercator + Zone + Lat
180, UTM 54 S, Universal Transverse Mercator + Zone + Lat
181, UTM 55 S, Universal Transverse Mercator + Zone + Lat
182, UTM 56 S, Universal Transverse Mercator + Zone + Lat
183, UTM 57 S, Universal Transverse Mercator + Zone + Lat
184, UTM 58 S, Universal Transverse Mercator + Zone + Lat
185, UTM 59 S, Universal Transverse Mercator + Zone + Lat
186, UTM 60 S, Universal Transverse Mercator + Zone + Lat
187, Satellite, Original satellite FoV geometry
188, Not known, Not known

7.2 Projection_Ellipsoid controlled list

```
##############################################################
#
# GODAE/GHRSST-PP Diagnostic Data Set (DDS) Projection_Ellipsoid controlled list
#
# VERSION 1
#
# Maintained by: Craig Donlon
#
##############################################################
#
# Revision History
#
# v1.0, 14-10-2002
# Created
#
#
####################################################
#
#
#Code, Short Description, Long Description
#
1, IAU76, IAU 1976
2, AIRY, Airy 1830
3, APL4.9, Appl. Physics. 1965
4, NWL9D, Naval Weapons Lab., 1965
5, MOD_AIRY, Modified Airy
6, ANDRAE, Andrae 1876 (Den., Iclnd.)
7, AUST_SA, Australian Natl & S. Amer. 1969
8, GRS67, GRS 67(IUGG 1967)
9, BESSEL, Bessel 1841
10, BESS_NAM, Bessel 1841 (Namibia)
11, CLRK66, Clarke 1866
12, CLRK80, Clarke 1880 mod.
13, CPM, Comm. des Poids et Mesures 1799
14, DELMBR, Delambre 1810 (Belgium)
15, ENGELIS, Engelis 1985
16, EVRST30, Everest 1830
17, EVRST48, Everest 1948
18, EVRST56, Everest 1956
19, EVRST69, Everest 1969
20, EVRSTSS, Everest (Sabah & Sarawak)
21, FSCHR60, Fischer (Mercury Datum) 1960
22, FSCHR60M, Modified Fischer 1960
23, FSCHR68, Fischer 1968
24, HELMERT, Helmert 1906
```

25, HOUGH, Hough
26, INTL, International 1909 (Hayford)
27, KRASS, Krassovsky, 1942
28, KAULA, Kaula 1961
29, LERCH, Lerch 1979
30, MPRTS, Maupertius 1738
31, NEW_INTL, New International 1967
32, PLESSIS, Plessis 1817 (France)
33, SEASIA, Southeast Asia
34, WALBECK, Walbeck
35, WGS60, WGS 60
36, WGS66, WGS 66
37, WGS72, WGS 72
38, WGS84, WGS 84
40, Not known, NOT KNOWN

8 Annex 3. Unidata UDUNITS List of Acceptable Units

```
# $Id: udunits.dat,v 1.11 1998/02/10 22:30:24 steve Exp $
#
# The first column is the unit name.  The second column indicates whether or
# not the unit name has a plural form (i.e. with an 's' appended).
# A 'P' indicates that the unit has a plural form, whereas, a 'S' indicates
# that the unit has a singular form only.  The remainder of the line is the
# definition for the unit.
#
# '#' is the to-end-of-line comment-character.
#
# NB: When adding to this table, be *very* careful to distinquish between
# the letter 'O' and the numeral zero '0'.  For example, the following two
# entries don't do what one might otherwise expect:
#
#           mercury_0C              mercury_32F
#           millimeter_Hg_0C        mm mercury_OC

#
# BASE UNITS.  These must be first and are identified by a nil definition.
#
ampere          P                       # electric current
count           P                       # dimensionless decimal number
candela         P                       # luminous intensity
kelvin          P                       # thermodynamic temperature
kilogram        P                       # mass
meter           P                       # length
mole            P                       # amount of substance
second          P                       # time
radian          P                       # plane angle

#
# CONSTANTS
#
percent         S 0.01
PI              S 3.14159265358979323846
bakersdozen     S 13
pair            P 2
ten             P 10
dozen           S 12
score           S 20
hundred         P 100
thousand        P 1.0e3
million         P 1.0e6

%               S percent
pi              S PI

#
```

```
# NB: All subsequent definitions must be given in terms of
# earlier definitions.  Forward referencing is not permitted.
#

#
# The following are non-base units of the fundamental quantities
#

bit                     P count                                 # unit of information

#
# UNITS OF ELECTRIC CURRENT
#
A                       S ampere
amp                     P ampere
abampere                P 10 ampere             # exact
gilbert                 P 7.957747e-1 ampere
statampere              P 3.335640e-10 ampere
biot                    P 10 ampere

#
# UNITS OF LUMINOUS INTENSITY
#
cd                      S candela
candle                  P candela

#
# UNITS OF THERMODYNAMIC TEMPERATURE
#
degree_Kelvin P kelvin
degree_Celsius          S kelvin @ 273.15
degree_Rankine          P kelvin/1.8
degree_Fahrenheit       P degree_Rankine @ 459.67

#C                      S degree_Celsius        # `C' means `coulomb'
Celsius                 S degree_Celsius
celsius                 S degree_Celsius
degree_centigrade       S degree_Celsius        # approx. was just `centigrade'
degC                    S degree_Celsius
degreeC                 S degree_Celsius
degree_C                S degree_Celsius
degree_c                S degree_Celsius
deg_C                   S degree_Celsius
deg_c                   S degree_Celsius
degK                    S kelvin
degreeK                 S kelvin
degree_K                S kelvin
degree_k                S kelvin
deg_K                   S kelvin
deg_k                   S kelvin
K                       S kelvin
Kelvin                  P kelvin

degF                    S degree_Fahrenheit
degreeF                 S degree_Fahrenheit
degree_F                S degree_Fahrenheit
degree_f                S degree_Fahrenheit
deg_F                   S degree_Fahrenheit
deg_f                   S degree_Fahrenheit
F                       S degree_Fahrenheit
Fahrenheit              P degree_Fahrenheit
fahrenheit              P degree_Fahrenheit

degR                    S degree_Rankine
degreeR                 S degree_Rankine
degree_R                S degree_Rankine
```

```
degree_r                S degree_Rankine
deg_R                   S degree_Rankine
deg_r                   S degree_Rankine
#R                      S degree_Rankine          # `R' means `roentgen'
Rankine                 P degree_Rankine
rankine                 P degree_Rankine

#
# UNITS OF MASS
#
assay_ton               P 2.916667e-2 kilogram    # was 2.916667e2 (typo!)
avoirdupois_ounce       P 2.834952e-2 kilogram
avoirdupois_pound       P 4.5359237e-1 kilogram   # exact
carat                   P 2e-4 kilogram
grain                   P 6.479891e-5 kilogram    # exact
gram                    P 1e-3 kilogram                      # exact
kg                      S kilogram
long_hundredweight      P 5.080235e1 kilogram
metric_ton              P 1e3 kilogram            # exact
pennyweight             P 1.555174e-3 kilogram
short_hundredweight     P 4.535924e1 kilogram
slug                    P 14.59390 kilogram
troy_ounce              P 3.110348e-2 kilogram
troy_pound              P 3.732417e-1 kilogram
atomic_mass_unit        P 1.66054e-27 kilogram    # was 1.66044e-27

tonne                   P metric_ton
apothecary_ounce        P troy_ounce
apothecary_pound        P avoirdupois_pound
pound                   P avoirdupois_pound
metricton               P metric_ton
gr                      S grain
scruple                 P 20 grain
apdram                  P 60 grain
apounce                 P 480 grain
appound                 P 5760 grain
atomicmassunit          P atomic_mass_unit
amu                     P atomic_mass_unit

t                       S tonne
lb                      P pound
bag                     P 94 pound
short_ton               P 2000 pound
long_ton                P 2240 pound

ton                     P short_ton
shortton                P short_ton
longton                 P long_ton

#
# UNITS OF LENGTH
#
angstrom                P decinanometer
astronomical_unit       P 1.495979e11 meter
fermi                   P 1e-15 meter             # exact
m                       S meter
metre                   P meter
light_year              P 9.46073e15 meter        # was ASTM's 9.46055e15 meter
micron                  P 1e-6 meter              # exact
mil                     P 2.54e-5 meter                      # exact
nautical_mile  P 1.852000e3 meter          # exact
parsec                  P 3.085678e16 meter
printers_point  P 3.514598e-4 meter

# God help us!  There's an international foot and a US survey foot and
# they're not the same!
```

```
# US Survey foot stuff:
US_survey_foot          S (1200/3937) meter       # exact
US_survey_feet          S US_survey_foot          # alias
US_survey_yard          P 3 US_survey_feet        # exact
US_survey_mile          P 5280 US_survey_feet     # exact
US_statute_mile         P US_survey_mile          # alias
rod                     P 16.5 US_survey_feet     # exact
pole                    P rod                                 # alias
perch                   S rod                                 # alias
perches                 S perch                               # alias
furlong                 P 660 US_survey_feet      # exact
fathom                  P 6 US_survey_feet        # exact

# International foot stuff:
international_inch      S 2.54 cm                 # exact
international_inches    S international_inch      # alias
international_foot      S 12 international_inches # exact
international_feet      S international_foot      # alias
international_yard      P 3 international_feet    # exact
international_mile      P 5280 international_feet # exact

# Alias unspecified units to the international units:
inch                    S international_inch      # alias
foot                    S international_foot      # alias
yard                    P international_yard      # alias
mile                    P international_mile      # alias

# The following should hold regardless:
inches                  S inch                                # alias
in                      S inches                  # alias
feet                    S foot                                # alias
ft                      S feet                                # alias
yd                      S yard                                # alias

chain                   P 2.011684e1 meter

printers_pica   P 12 printers_point           # exact
astronomicalunit        P astronomical_unit
au                      S astronomical_unit
nmile                   P nautical_mile
nmi                     S nautical_mile

pica                    P printers_pica
big_point               P inch/72                 # exact
barleycorn              P inch/3

arpentlin               P 191.835 foot

#
# UNITS OF AMOUNT OF SUBSTANCE
#
mol                     S mole

#
# UNITS OF TIME
#
day                     P 8.64e4 second                       # exact
hour                    P 3.6e3 second                        # exact
minute                  P 60 second               # exact
s                       S second
sec                     P second
shake                   P 1e-8 second             # exact
sidereal_day    P 8.616409e4 second
sidereal_hour   P 3.590170e3 second
sidereal_minute         P 5.983617e1 second
```

```
sidereal_second		P 0.9972696 second
sidereal_year	P 3.155815e7 second
# Interval between 2 successive passages of sun through vernal equinox
# (365.242198781 days -- see
# http://www.ast.cam.ac.uk/pubinfo/leaflets/,
# http://aa.usno.navy.mil/AA/
# and http://adswww.colorado.edu/adswww/astro_coord.html):
tropical_year	P 3.15569259747e7 second
lunar_month		P 29.530589 day

common_year			P 365 day			# exact: 153600e7 seconds
leap_year		P 366 day		# exact
Julian_year		P 365.25 day		# exact
Gregorian_year		P 365.2425 day			# exact
sidereal_month		P 27.321661 day
tropical_month		P 27.321582 day
d			S day
min			P minute
hr			P hour
h			S hour
fortnight		P 14 day		# exact
week			P 7 day				# exact
jiffy			S 0.01 second		# believe it or not!
jiffies			S jiffy				# assumed plural spelling

year			P tropical_year

yr			P year
a			S year				# "anno"
eon			P 1e9 year		# fuzzy
month			P year/12		# on average

#
# UNITS OF PLANE ANGLE
#
#rad			P radian		# `rad' means `grey'
circle			P 2 pi radian
angular_degree		P (pi/180) radian

turn			P circle
degree			P angular_degree
degree_north	S angular_degree
degree_east		S angular_degree
degree_true		S angular_degree
arcdeg			P angular_degree
angular_minute		P angular_degree/60
angular_second		P angular_minute/60
grade			P 0.9 angular_degree	# exact

degrees_northS degree_north
degreeN			S degree_north
degree_N		S degree_north
degreesN		S degree_north
degrees_N		S degree_north

degrees_east	S degree_east
degreeE			S degree_east
degree_E		S degree_east
degreesE		S degree_east
degrees_E		S degree_east

degree_west		S -1 degree_east
degrees_west		S degree_west
degreeW		S degree_west
degree_W		S degree_west
degreesW		S degree_west
```

```
degrees_W          S degree_west

degrees_true            S degree_true
degreeT                 S degree_true
degree_T                S degree_true
degreesT                S degree_true
degrees_T               S degree_true

arcminute               P angular_minute
arcsecond               P angular_second

arcmin                  P arcminute
arcsec                  P arcsecond

#
# The following are derived units with special names.  They are useful for
# defining other derived units.
#
steradian               P radian2
hertz                   S 1/second
newton                  P kilogram.meter/second2
coulomb                 P ampere.second
lumen                   P candela steradian
becquerel               P 1/second              # SI unit of activity of a
#                                                     # radionuclide
standard_free_fall      S 9.806650 meter/second2    # exact

pascal                  P newton/meter2
joule                   P newton.meter
hz                      S hertz
sr                      S steradian
force                   S standard_free_fall
gravity                 S standard_free_fall
free_fall               S standard_free_fall
lux                     S lumen/meter2
sphere                  P 4 pi steradian

luxes                   S lux
watt                    P joule/second
gray                    P joule/kilogram        # absorbed dose. derived unit
sievert                 P joule/kilogram        # dose equivalent. derived unit
conventional_mercury    S gravity 13595.10 kg/m3
mercury_0C              S gravity 13595.1 kg/m3     # was 13595.065
mercury_60F             S gravity 13556.8 kg/m3     # was 13556.806
conventional_water      S gravity 1000 kg/m3        # exact
water_4C                S gravity 999.972 kg/m3     # was 999.97226
water_60F               S gravity 999.001 kg/m3     # was 999.00072
g                       S gravity               # approx. should be `local'

volt                    P watt/ampere
mercury_32F             S mercury_0C
water_39F               S water_4C              # actually 39.2 F
mercury                 S conventional_mercury  # was mercury_32F
water                   S conventional_water    # was water_4C

farad                   P coulomb/volt
ohm                     P volt/ampere
siemens                 S ampere/volt
weber                   P volt.second
Hg                      S mercury
hg                      S mercury
H2O                     S water
h2o                     S water

tesla                   P weber/meter2
henry                   P weber/ampere
```

```
#
# The following are compound units: units whose definitions consist
# of two or more base units.  They may now be defined in terms of the
# preceding units.
#

#
# ACCELERATION
#
gal                     P 1e-2 meter/second2        # exact

#
# Area
#
are                     P 1e2 m2                    # exact
barn                    P 1e-28 m2                  # exact
circular_mil    P 5.067075e-10 m2
darcy                   P 9.869233e-13 m2           # permeability of porous solids
hectare                 P 1e4 m2                    # exact
acre                    P 160 rod2                  # exact

#
# ELECTRICITY AND MAGNETISM
#
abfarad                 P 1e9 farad                 # exact
abhenry                 P 1e-9 henry                # exact
abmho                   P 1e9 siemens               # exact
abohm                   P 1e-9 ohm                  # exact
abvolt                  P 1e-8 volt                 # exact
C                       S coulomb
e                       S 1.60217733-19 coulomb     # was 1.6021917e-19
chemical_faraday        P 9.64957e4 coulomb
physical_faraday        P 9.65219e4 coulomb
C12_faraday             P 9.648531e4 coulomb
gamma                   P 1e-9 tesla                # exact
gauss                   S 1e-4 tesla                # exact
H                       S henry
maxwell                 P 1e-8 weber                # exact
oersted                 P 7.957747e1 ampere/meter
S                       S siemens
statcoulomb             P 3.335640e-10 coulomb
statfarad               P 1.112650e-12 farad
stathenry               P 8.987554e11 henry
statmho                 P 1.112650e-12 siemens
statohm                 P 8.987554e11 ohm
statvolt                P 2.997925e2 volt
T                       S tesla
unit_pole               P 1.256637e-7 weber
V                       S volt
Wb                      S weber
mho                     P siemens
Oe                      S oersted
faraday                 P C12_faraday                       # charge of 1 mole of
#                                                            # electrons

#
# ENERGY (INCLUDES WORK)
#
electronvolt    P 1.602177e-19 joule
erg                     P 1e-7 joule                # exact
IT_Btu                  P 1.05505585262e3 joule     # exact, was 1.055056e3
EC_therm                P 1.05506e8 joule           # exact
thermochemical_calorie  P 4.184000 joule            # exact
IT_calorie              P 4.1868 joule              # exact
J                       S joule
```

```
ton_TNT                 S 4.184e9 joule
US_therm                P 1.054804e8 joule          # exact
watthour                P watt hour

therm                   P US_therm
Wh                      S watthour
Btu                     P IT_Btu
calorie                 P IT_calorie
electron_volt   P electronvolt

thm                     S therm
cal                     S calorie
eV                      S electronvolt
bev                     S gigaelectron_volt

#
# FORCE
#
dyne                    P 1e-5 newton               # exact
pond                    P 9.806650e-3 newton        # exact, was 1.806650e-3 (typo)
force_kilogram          S 9.806650 newton           # exact
force_ounce             S 2.780139e-1 newton
force_pound             S 4.4482216152605 newton# exact
poundal                 P 1.382550e-1 newton
N                       S newton
gf                      S gram force

force_gram              P 1e-3 force_kilogram
force_ton               P 2000 force_pound          # exact
lbf                     S force_pound
ounce_force             S force_ounce
kilogram_force          S force_kilogram
pound_force             S force_pound
ozf                     S force_ounce
kgf                     S force_kilogram
kip                     P 1000 lbf
ton_force               S force_ton
gram_force              S force_gram

#
# HEAT
#
clo                     P 1.55e-1 kelvin.meter2/watt

#
# LIGHT
#
lm                      S lumen
lx                      S lux
footcandle              P 1.076391e-1 lux
footlambert             P 3.426259 candela/meter2
lambert                 P (1e4/PI) candela/meter2   # exact
stilb                   P 1e4 candela/meter2        # exact
phot                    P 1e4 lumen/meter2          # exact
nit                     P 1 candela/meter2          # exact
langley                 P 4.184000e4 joule/meter2   # exact
blondel                 P candela/(pi meter2)

apostilb                P blondel
nt                      S nit
ph                      S phot
sb                      S stilb

#
# MASS PER UNIT LENGTH
#
```

```
denier                    P 1.111111e-7 kilogram/meter
tex                       P 1e-6 kilogram/meter      # exact

#
# MASS PER UNIT TIME (INCLUDES FLOW)
#
perm_0C                   S 5.72135e-11 kg/(pascal second meter2)
perm_23C                  S 5.74525e-11 kg/(pascal second meter2)

#
# POWER
#
voltampere                P volt ampere
VA                        S volt ampere
boiler_horsepower         P 9.80950e3 watt
shaft_horsepower          P 7.456999e2 watt
metric_horsepower         P 7.35499 watt
electric_horsepower       P 7.460000e2 watt          # exact
W                         S watt
water_horsepower          P 7.46043e2 watt
UK_horsepower             P 7.4570e2 watt
refrigeration_ton         P 12000 Btu/hour

horsepower                P shaft_horsepower
ton_of_refrigeration      P refrigeration_ton

hp                        S horsepower

#
# PRESSURE OR STRESS
#
bar                       P 1e5 pascal               # exact
standard_atmosphere       P 1.01325e5 pascal         # exact
technical_atmosphere      P 1 kg gravity/cm2         # exact
inch_H2O_39F S inch water_39F
inch_H2O_60F S inch water_60F
inch_Hg_32F               S inch mercury_32F
inch_Hg_60F               S inch mercury_60F
millimeter_Hg_0C          S mm mercury_0C
footH2O                   S foot water
cmHg                      S cm Hg
cmH2O                     S cm water
Pa                        S pascal
inch_Hg                   S inch Hg
inch_hg                   S inch Hg
inHg                      S inch Hg
in_Hg                     S inch Hg
in_hg                     S inch Hg
millimeter_Hg  S mm Hg
mmHg                      S mm Hg
mm_Hg                     S mm Hg
mm_hg                     S mm Hg
torr                      P mm Hg
foot_H2O                  S foot water
ftH2O                     S foot water
psi                       S 1 pound gravity/in2
ksi                       S kip/in2
barie                     P 0.1 newton/meter2

at                        S technical_atmosphere
atmosphere                P standard_atmosphere
atm                       P standard_atmosphere
barye                     P barie

#
# RADIATION UNITS
```

```
#
Bq                      S becquerel
curie                   P 3.7e10 becquerel        # exact
rem                     P 1e-2 sievert            # dose equivalent. exact
rad                     P 1e-2 gray               # absorbed dose. exact
roentgen                P 2.58e-4 coulomb/kg      # exact
Sv                      S sievert
Gy                      S gray

Ci                      S curie
R                       S roentgen
rd                      S rad

#
# VELOCITY (INCLUDES SPEED)
#
c                       S 2.997925e+8 meter/sec
knot                    P nautical_mile/hour

knot_international      S knot
international_knot      S knot
kt                      P knot

#
# VISCOSITY
#
poise                   S 1e-1 pascal second      # absolute viscosity.
#                                                             # exact
stokes                  S 1e-4 meter2/second      # exact
rhe                     S 10/(pascal second)      # exact
St                      S stokes

#
# VOLUME (INCLUDES CAPACITY)
#
acre_foot               S 1.233489e3 m3           # but `acre foot' is 1233.4867714897
                                                  # meters^3. Odd.
board_foot              S 2.359737e-3 m3
bushel                  P 3.523907e-2 m3
UK_liquid_gallon        P 4.546090e-3 m3          # exact. was 4.546092e-3
Canadian_liquid_gallon  P 4.546090e-3 m3          # exact
US_dry_gallon P 4.404884e-3 m3
US_liquid_gallon        P 3.785412e-3 m3
cc                      S cm3
liter                   P 1e-3 m3                 # exact. However, from 1901 to
#                                                             # 1964, 1 liter = 1.000028 dm3
stere                   P 1 m3                                # exact
register_ton    P 2.831685 m3           # was 3.831685 (typo!)

US_dry_quart    P US_dry_gallon/4
US_dry_pint             P US_dry_gallon/8

US_liquid_quart         P US_liquid_gallon/4
US_liquid_pint  P US_liquid_gallon/8
US_liquid_cup   P US_liquid_gallon/16
US_liquid_gill  P US_liquid_gallon/32
US_fluid_ounce          P US_liquid_gallon/128
US_liquid_ounce         P US_fluid_ounce

UK_liquid_quart         P UK_liquid_gallon/4
UK_liquid_pint  P UK_liquid_gallon/8
UK_liquid_cup   P UK_liquid_gallon/16
UK_liquid_gill  P UK_liquid_gallon/32
UK_fluid_ounce          P UK_liquid_gallon/160
UK_liquid_ounce         P UK_fluid_ounce
```

```
liquid_gallon   P US_liquid_gallon
fluid_ounce                     P US_fluid_ounce
#liquid_gallon P UK_liquid_gallon
#fluid_ounce  P UK_fluid_ounce

dry_quart                       P US_dry_quart
dry_pint                        P US_dry_pint

liquid_quart    P liquid_gallon/4
liquid_pint                     P liquid_gallon/8

gallon                          P liquid_gallon
barrel                          P 42 US_liquid_gallon          # petroleum industry definition
quart                           P liquid_quart
pint                            P liquid_pint
cup                             P liquid_gallon/16
gill                            P liquid_gallon/32
tablespoon                      P US_fluid_ounce/2
teaspoon                        P tablespoon/3
peck                            P bushel/4

oz                              P fluid_ounce
floz                            S fluid_ounce
acre_feet                       S acre_foot
board_feet                      S board_foot
Tbl                             P tablespoon
Tbsp                            S tablespoon
tbsp                            S tablespoon
Tblsp                           S tablespoon
tblsp                           S tablespoon
litre                           P liter
L                               S liter
l                               S liter
tsp                             S teaspoon
pk                              S peck
bu                              S bushel

fldr                            S floz/8
dram                            P floz/16

bbl                             S barrel
firkin                          P barrel/4                     # exact but barrel is vague
pt                              S pint
dr                              S dram


#
# COMPUTERS AND COMMUNICATION
#
baud                            S 1/second                     # exact
b                               S bit
bps                             S bit/second
cps                             S hertz
Bd                              S baud

#
# MISC
#
kayser                          P 1e2/meter                    # exact
rps                             S hertz
rpm                             S hertz/60
geopotential  S gravity
work_year                       P 2056 hours
work_month                      P work_year/12

gp                              S geopotential
```

dynamic	S geopotential

[End of document]